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H4D DLAB D714 D747 D748 D752 D773 D775 D781 D783
H4J JGP
U1S S1142 S1865 S1887 S1917

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INT CL⁶ B60J 3/04 3/06 , B60R 1/08 21/00 22/20 22/48

(54) Abstract Title
Vehicle interior monitoring system

(57) An interior monitoring system for a motor vehicle includes pattern recognition means to identify an occupant or content of the vehicle, means to determine the location of said object or occupant and output means to control another system of the vehicle in response to the location of said object or occupant.

The pattern recognition means can be a passive or active infra red, radar, laser or ultrasonic system.

The function controlled can be the airbag system, seat belt height, windscreen transmissivity, rearview mirror reflectance, opening of the electric windows, the air conditioning system, the hi-fi system, a driver attentiveness alarm system, a security system or carphone microphone direction control system.
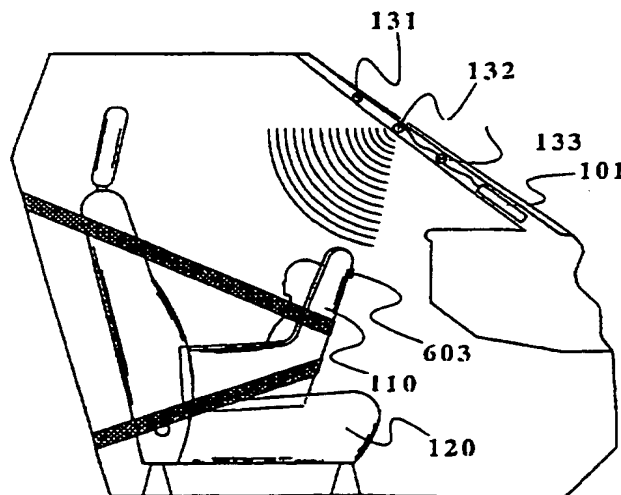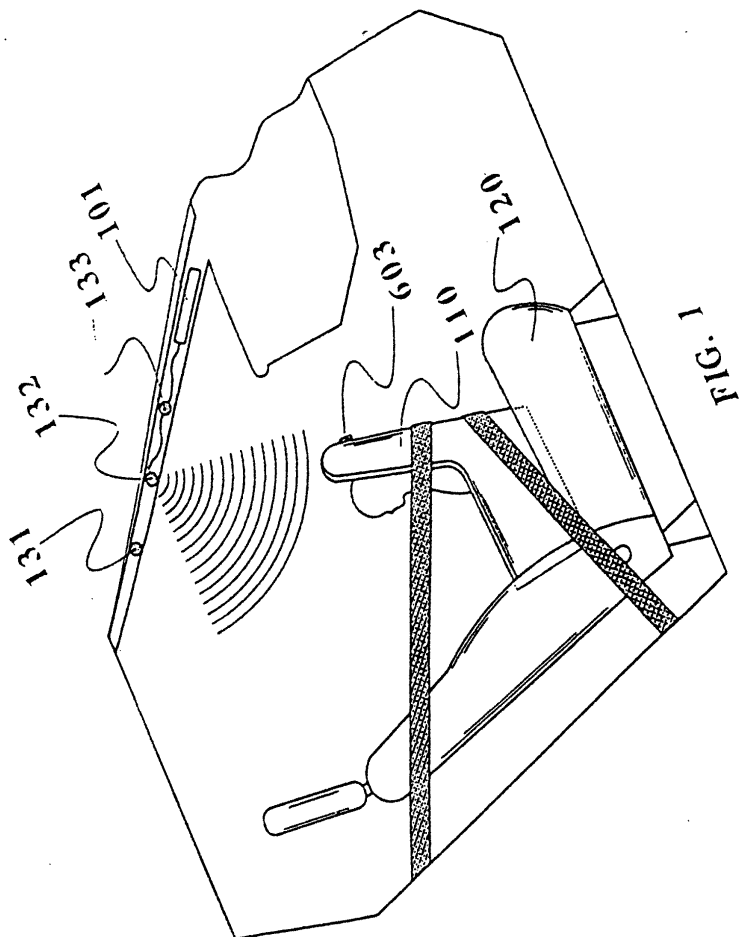

FIG. 1

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(74) Agent and/or Address for Service
        Anthony Cundy & Co
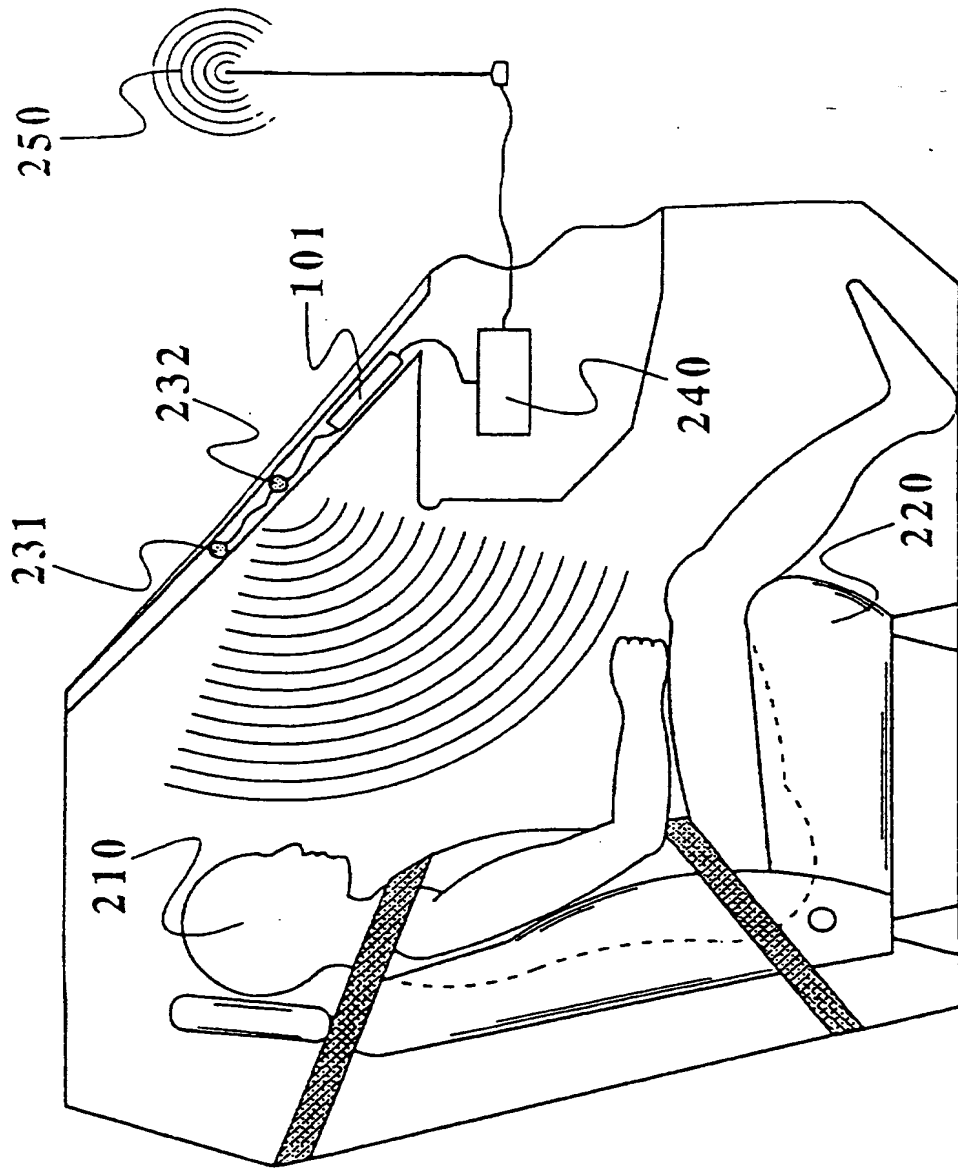   **1 Olton Bridge, 245 Warwick Road, SOLIHULL,**
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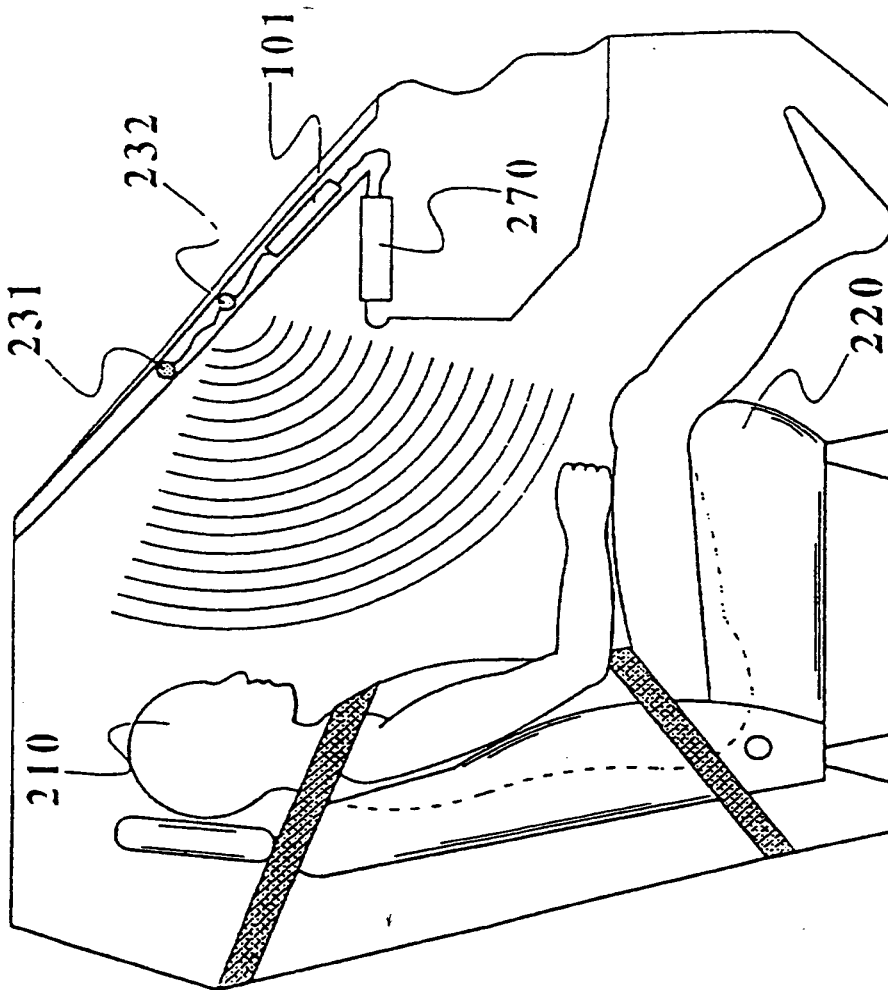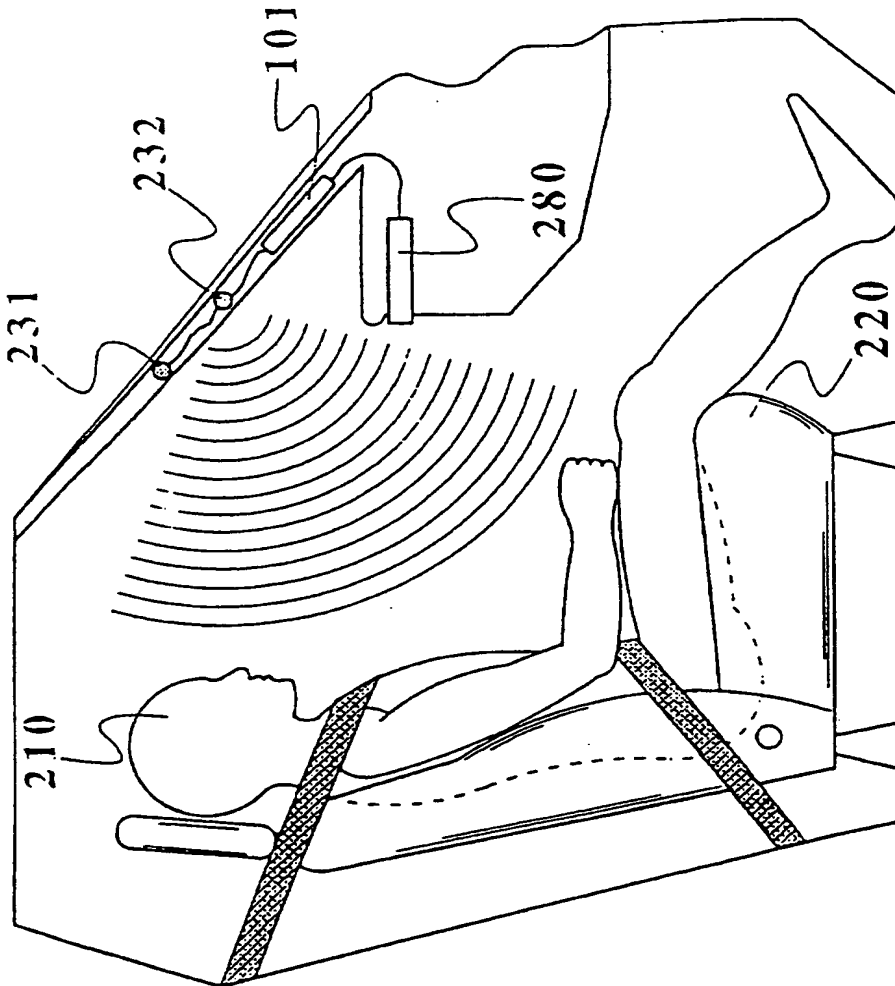
FIG. 1

FIG. 2

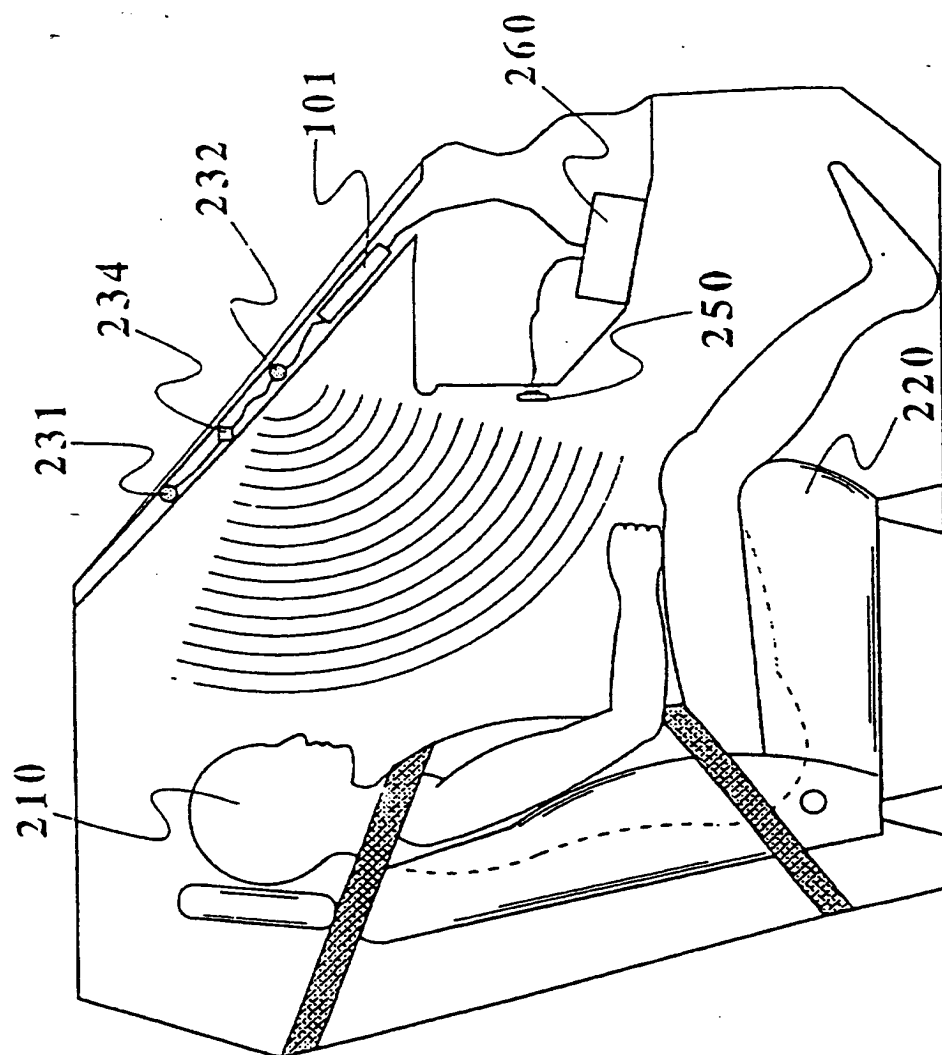*FIG. 3*

FIG. 4

FIG. 5
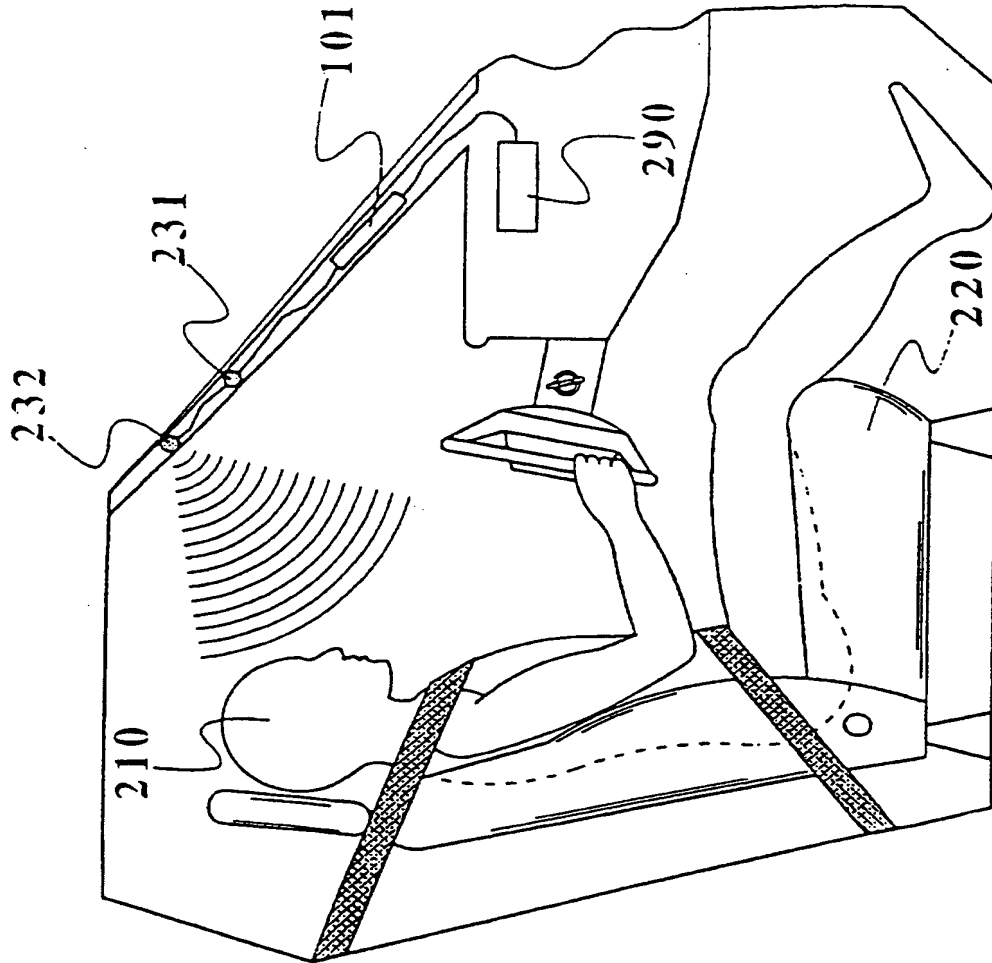
FIG. 6
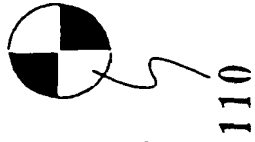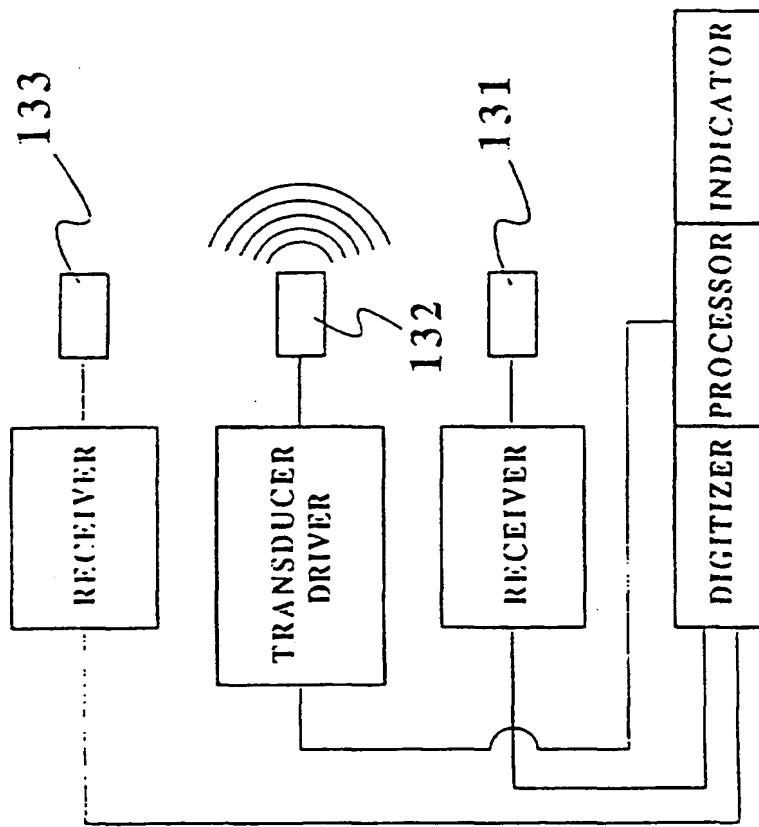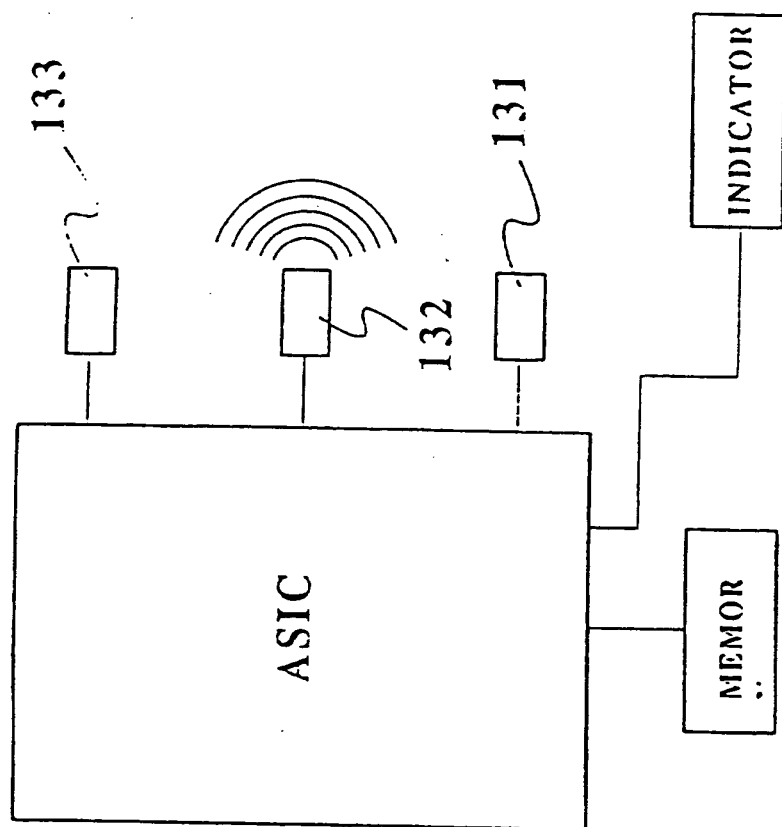
110

133

132

131

RECEIVER

TRANSDUCER DRIVER

RECEIVER

DIGITIZER | PROCESSOR | INDICATOR

FIG. 7A

FIG. 7B

131
132
133
101

295

FIG. 8

334

330

340

FIG. 9

FIG. 10

FIG. 11

FIG. 12

405

412

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462

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460

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210

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402

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FIG. 13

232

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642

101

641

FIG. 14

FIG. 15

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611 613 612

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FIG. 16

702
704

FIG. 17

231 233 232

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FIG. 18

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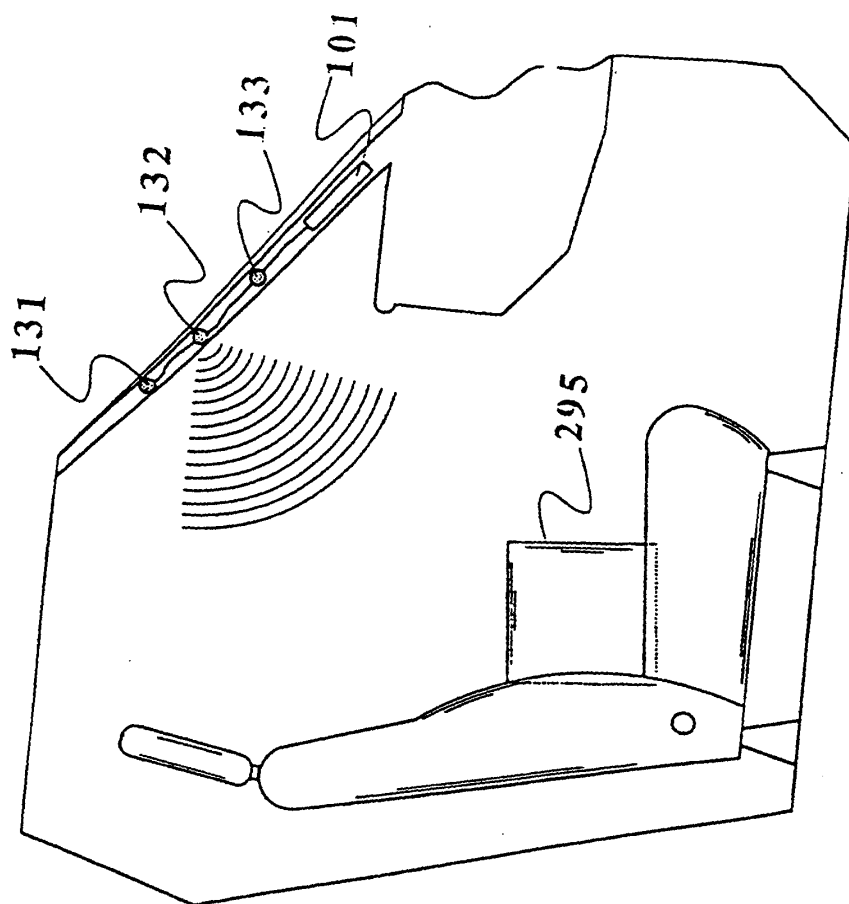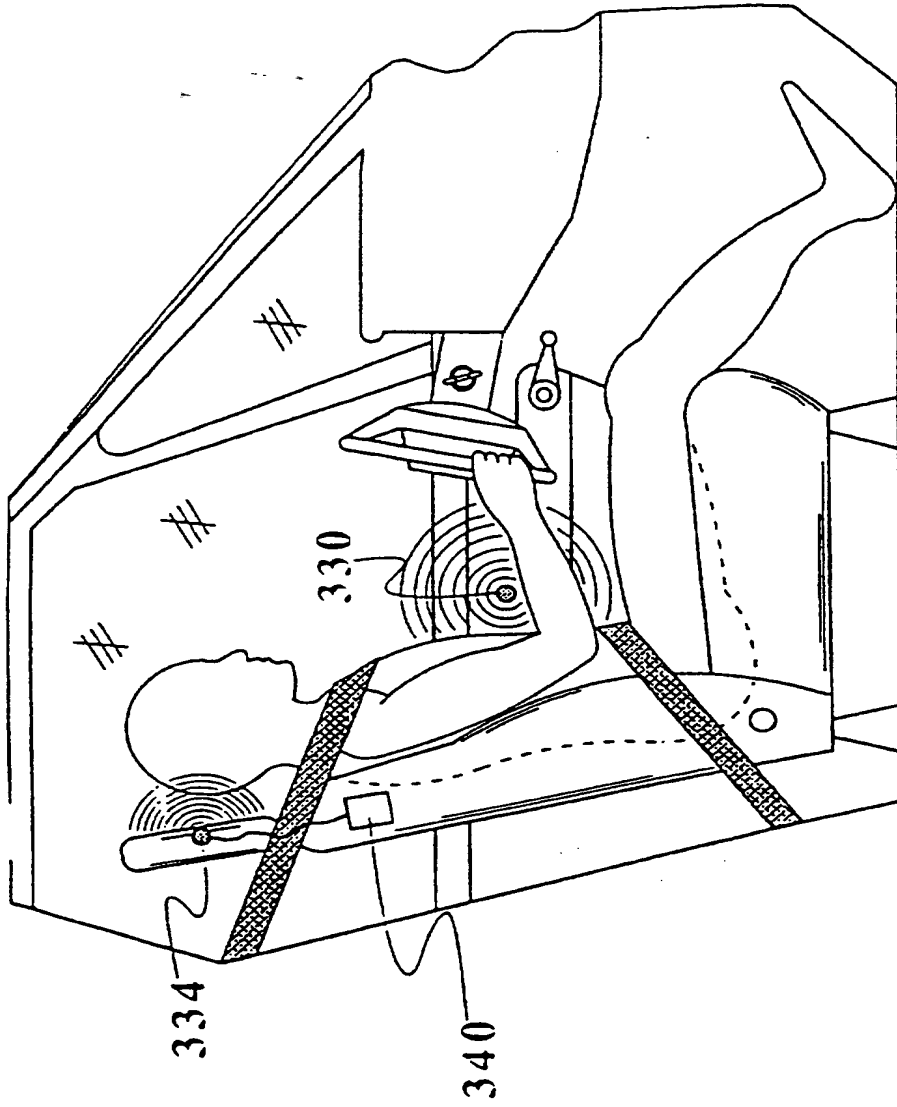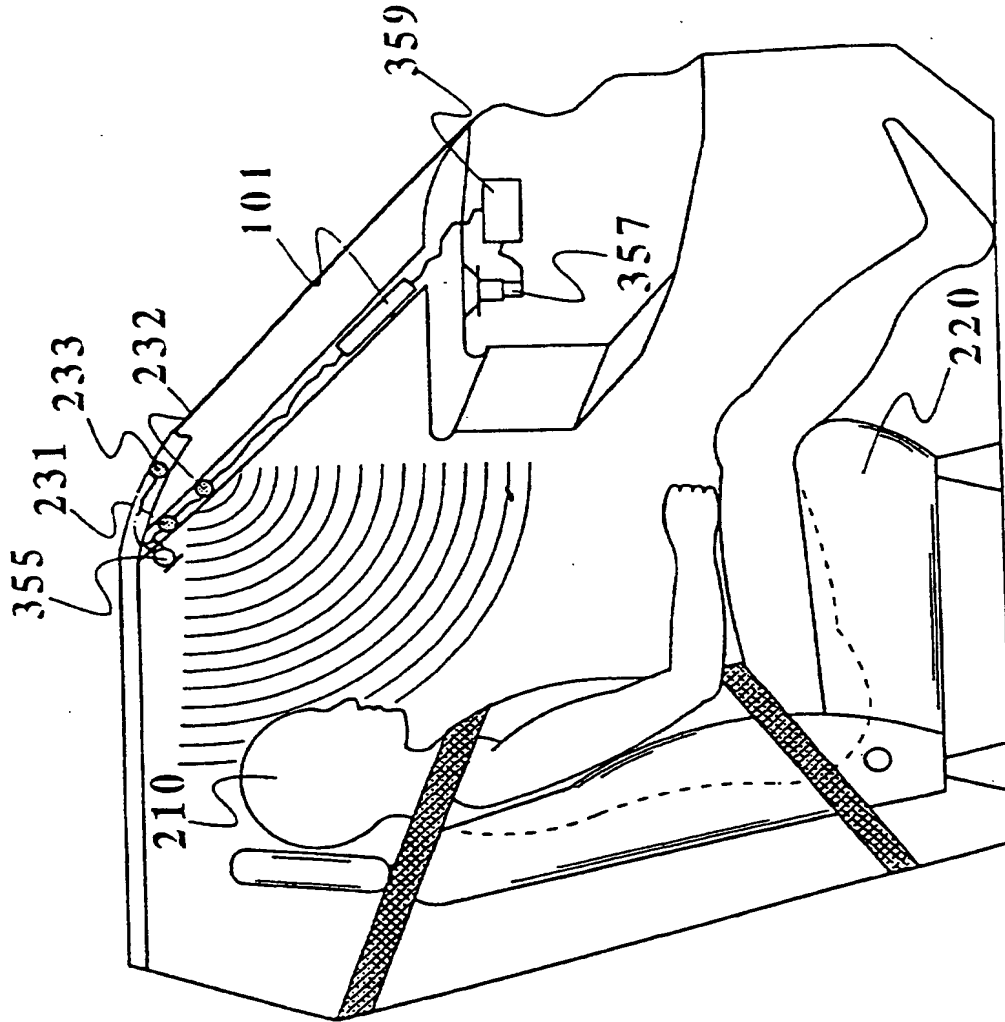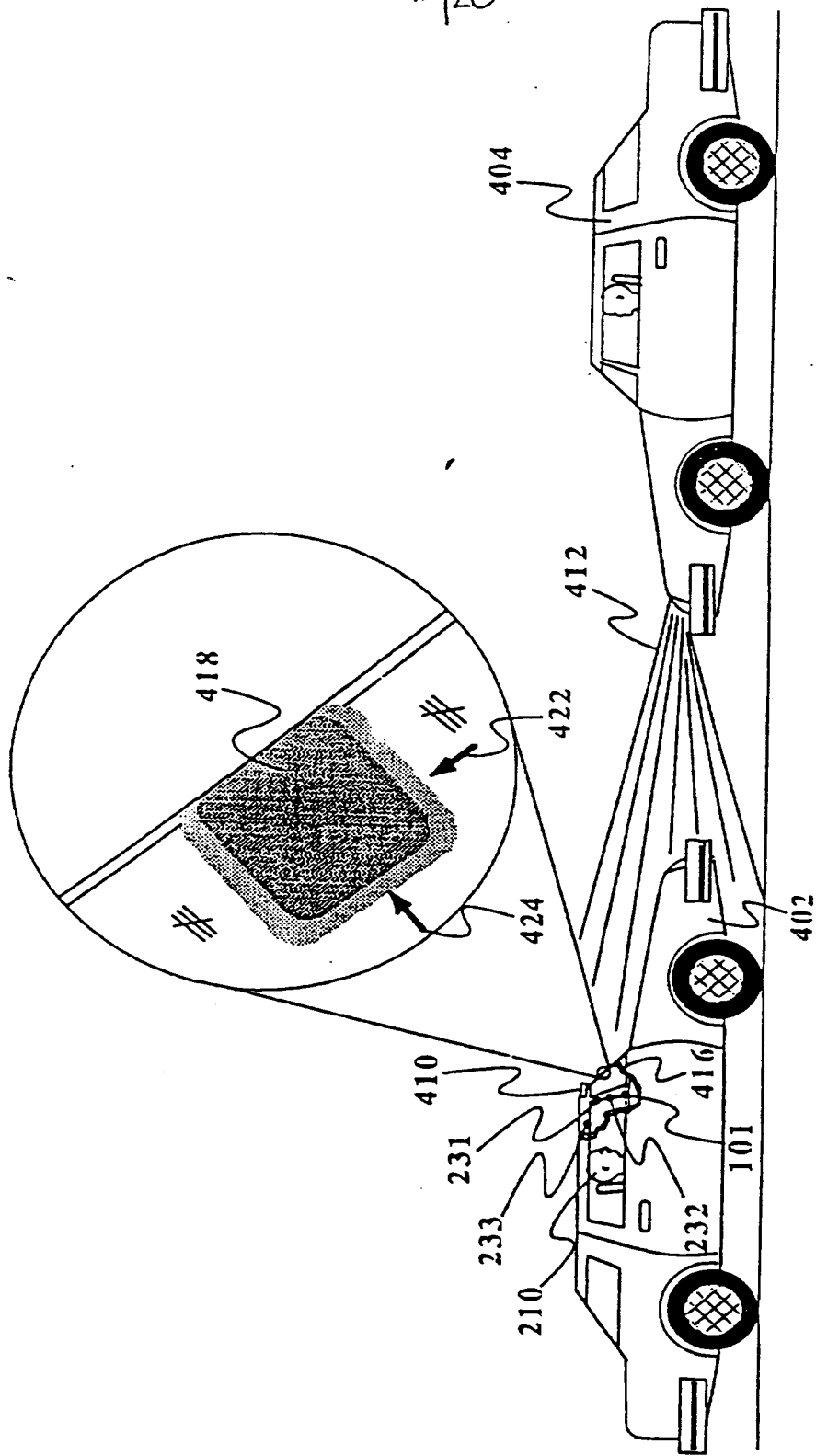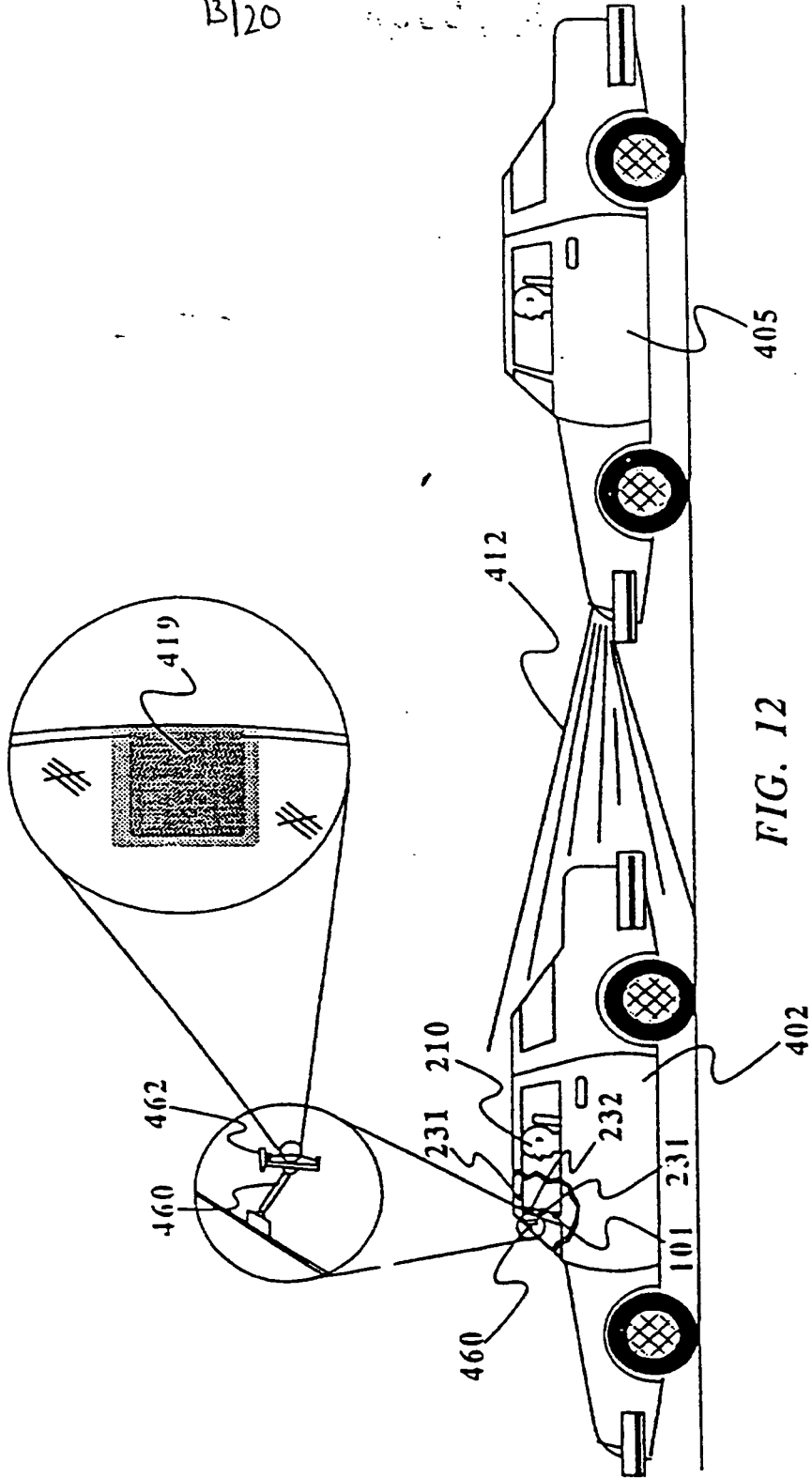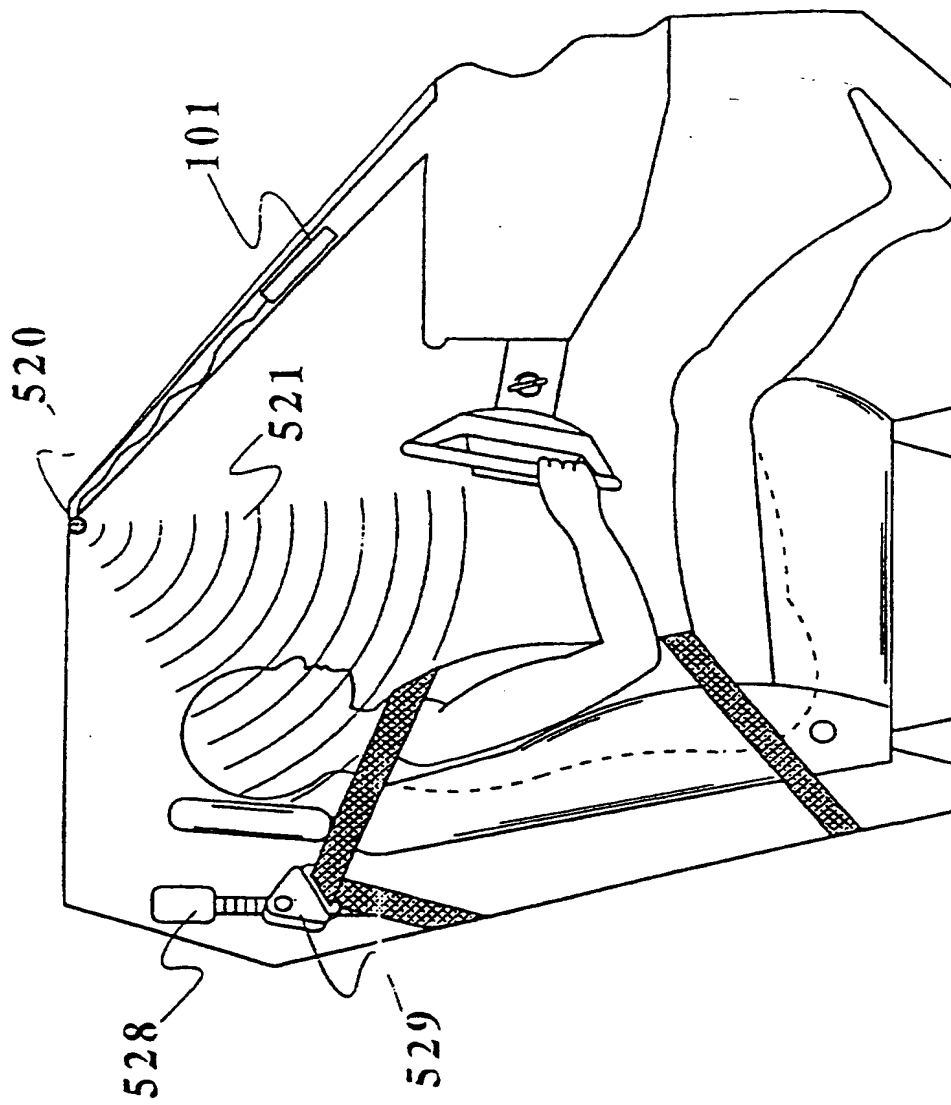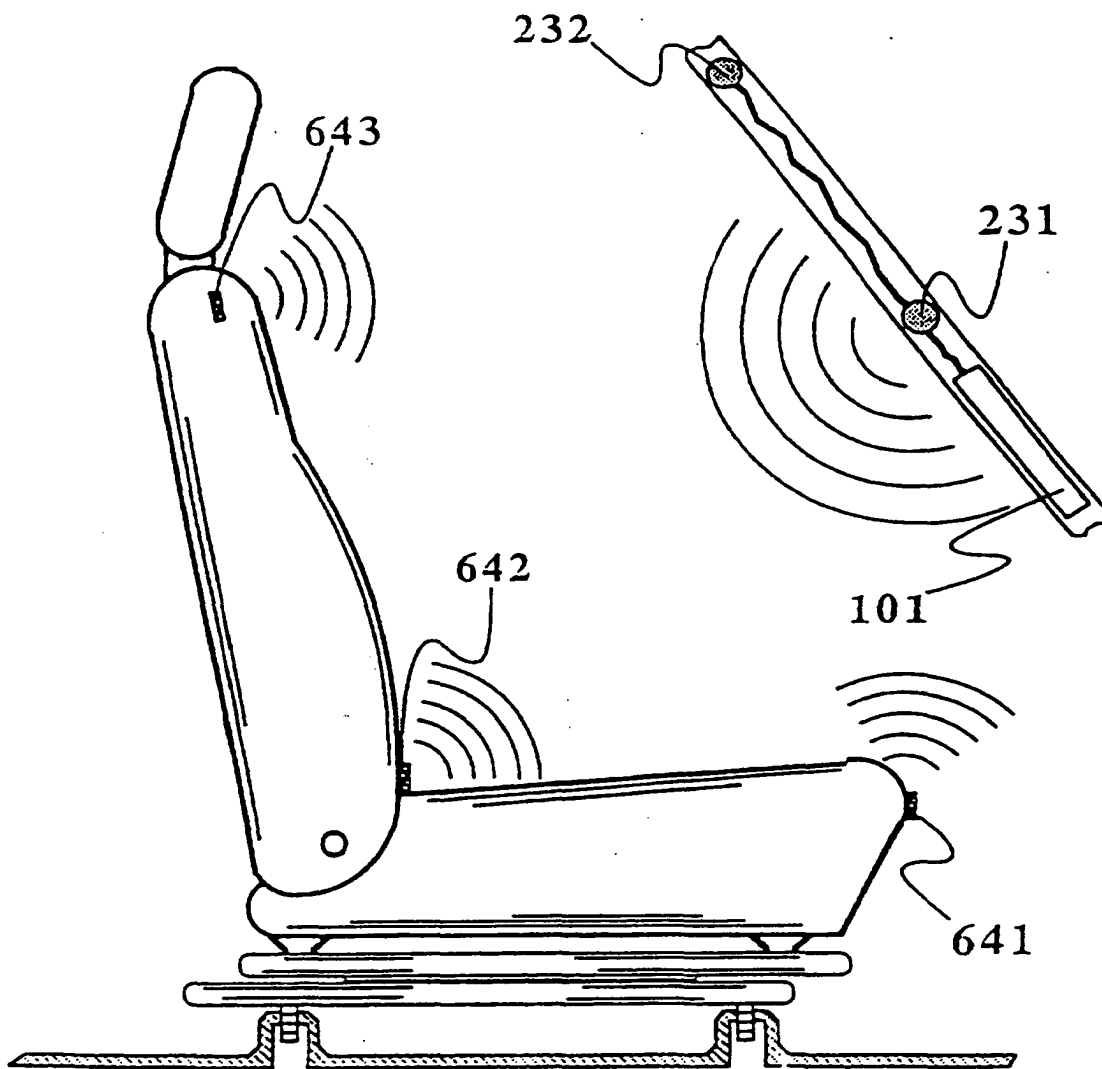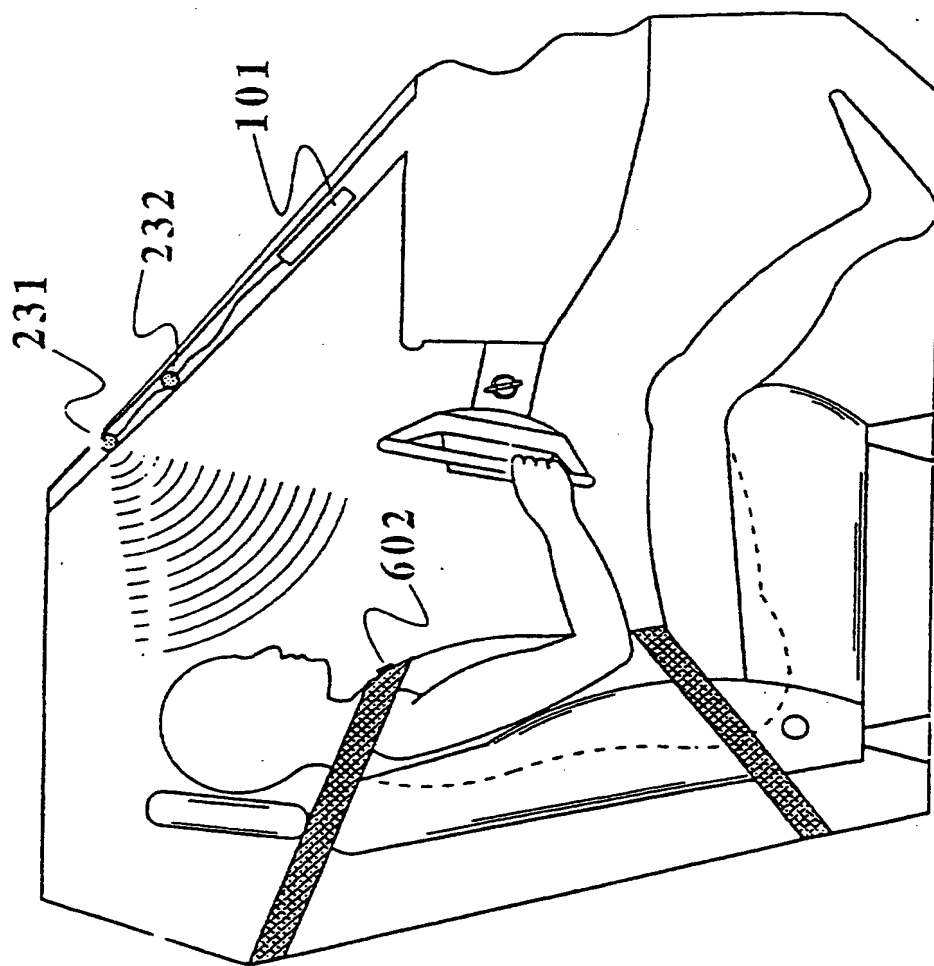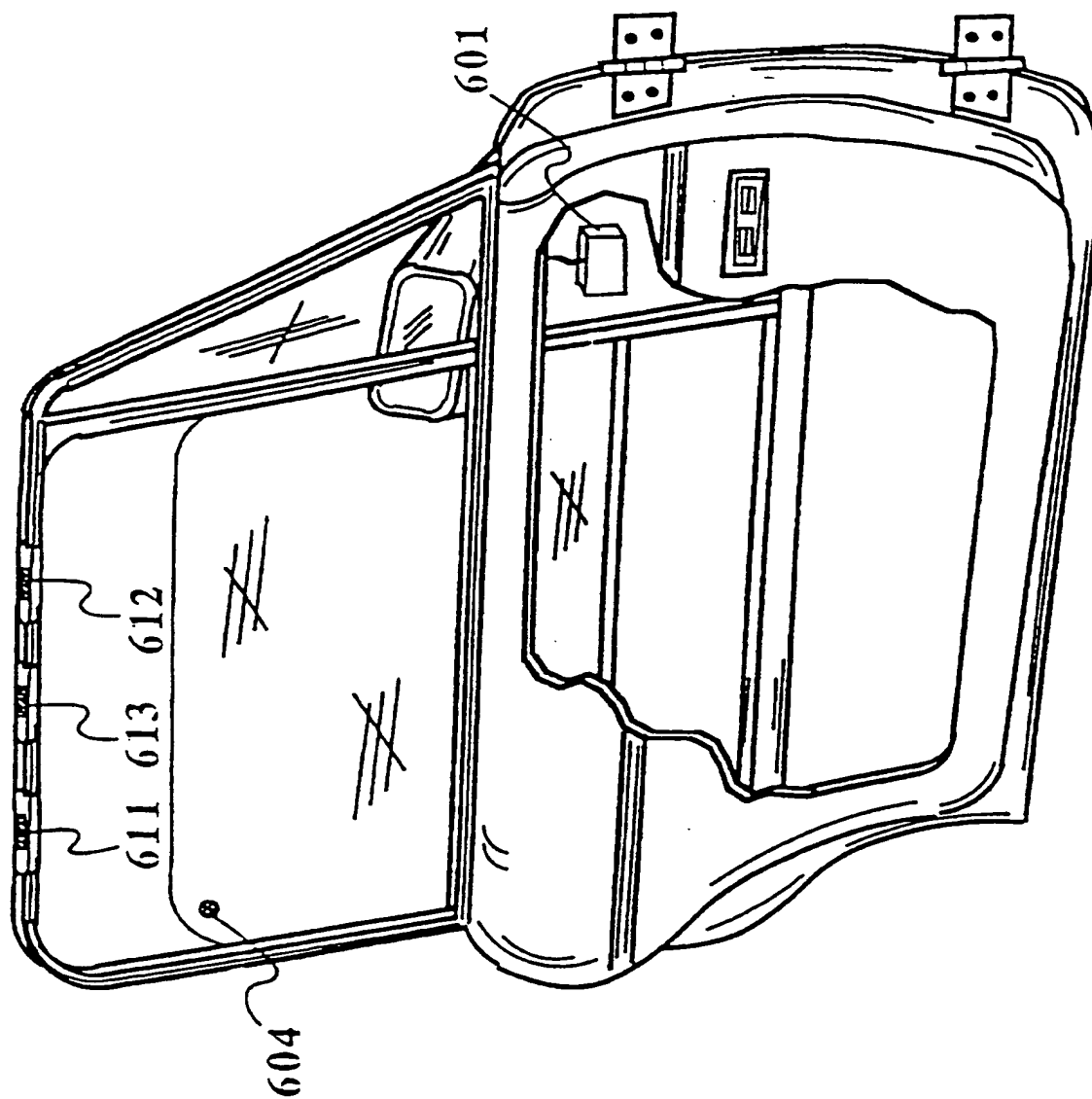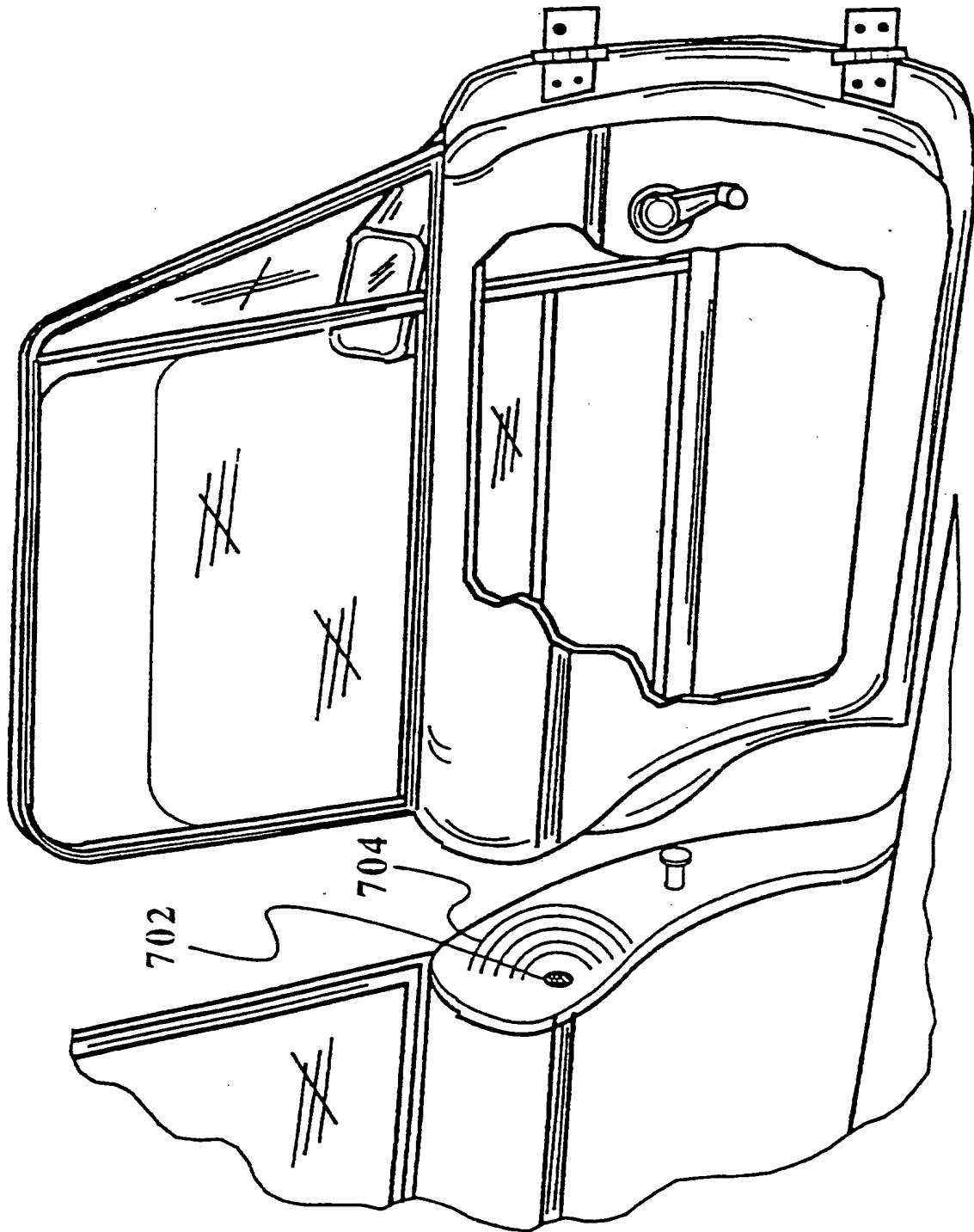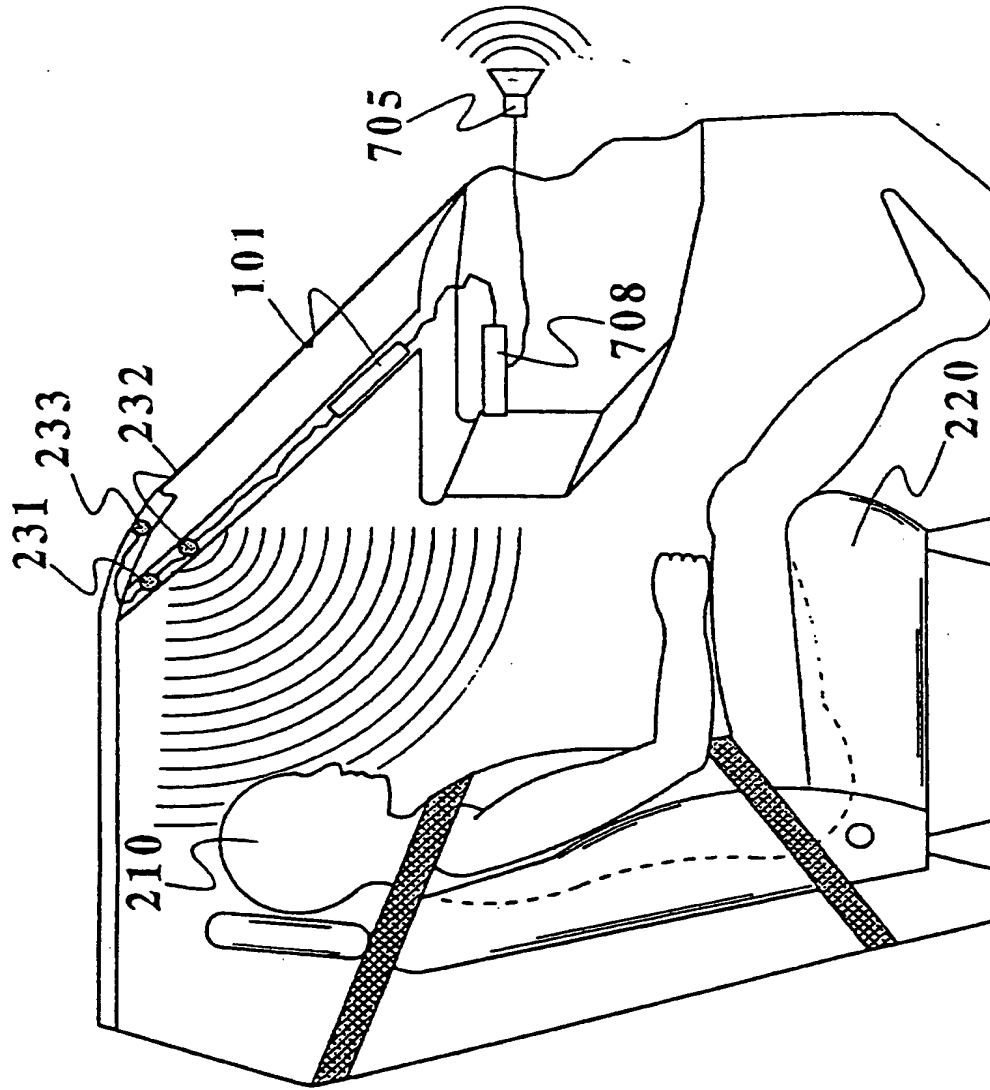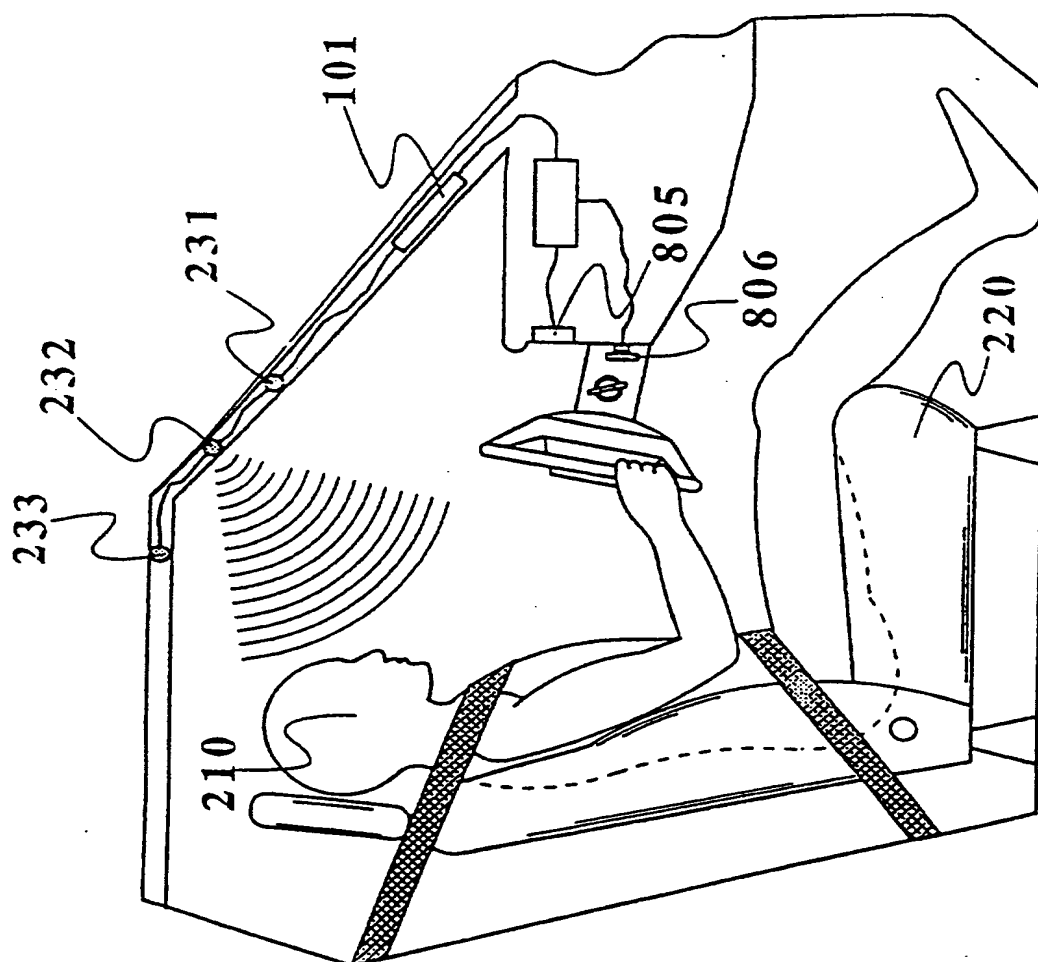
FIG. 19

VEHICLE INTERIOR IDENTIFICATION AND MONITORING SYSTEM

BACKGROUND OF THE INVENTION

In 1984 the National Highway Traffic Safety Administration (NHTSA) of the U.S. Department of Transportation issued a requirement for frontal crash protection of automobile occupants. This regulation mandated ''passive occupant restraints'' for all passenger cars by 1992. A more recent regulation requires both driver and passenger side airbags on all passenger cars and light trucks by 1998. In addition, the demand for airbags is accelerating in both Europe and Japan and it is expected that, within a few years, all vehicles produced in these areas (36 million vehicles) and eventually worldwide (50 million vehicles) will be equipped with airbags as standard equipment.

Whereas thousands of lives have been saved by airbags, significant improvements can be made. As discussed in detail in copending patent application 08/040,978 cross-referenced above, and included herein by reference, for a variety of reasons vehicle occupants can get too close to

the airbag before it deploys and can be seriously injured or killed.

Also, a child in a rear facing child seat which is placed on the right front passenger seat is in danger of being seriously injured if the passenger airbag deploys. This has now become an industry wide concern and the US automobile industry is urgently searching for a solution which will prevent the deployment of the passenger side airbag if a rear facing child seat is present. An improvement on the invention disclosed in the referenced copending patent application as will be disclosed in greater detail below, includes more sophisticated means to identify objects within the passenger compartment and will solve this problem.

Initially these systems will solve the out-of-position occupant and the rear facing child seat problems related to current airbag systems and prevent unneeded deployments when a seat is unoccupied. Airbags are now under development to protect rear seat occupants in vehicle crashes. A system will therefore be needed to detect the presence of occupants, determine if they are out-of-position and to identify the presence of a rear facing child seat in the rear seat. Future automobiles can be expected to have eight or more airbags as protection is sought for rear seat occupants and from side impacts. In addition to eliminating the disturbance of unnecessary airbag deployments, the cost of replacing these airbags

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will be excessive if they all deploy in an accident. The
improvements described below minimize this cost by not
deploying an airbag for a seat which is not occupied by a
human being. An occupying item of a seat may be a living
occupant such as a human being or dog, another living
organism such as a plant, or an inanimate object such as a
box or bag of groceries.

A device to monitor the vehicle interior and identify
its contents is needed to solve these and many other
problems. For example, once a Vehicle Interior
identification and Monitoring System (VIMS) for identifying
and monitoring the contents of a vehicle is in place, many
other products become possible including the following:

Inflators now exist which will adjust the amount of gas
flowing to the airbag to account for the size and position
of the occupant and for the severity of the accident. The
vehicle identification and monitoring system of this
invention will control such inflators based on the presence
and position of vehicle occupants or of a rear facing child
seat.

Side impact airbag systems will begin appearing on 1995
vehicles. The danger of deployment induced injuries will
exist for side impact airbags as they now do for frontal
impact airbags. A child with his head against the airbag
is such an example. The system of this invention will
minimize such injuries.

Future vehicles may be provided with a standard cellular phone as well as the Global Positioning System (GPS), an automobile navigation or location system which is scheduled to be available on at least one vehicle model in 1998. In the event of an accident, the phone may automatically call 911 for emergency assistance and report the exact position of the vehicle. If the vehicle also has a system as described below for monitoring each seat location, the number and perhaps the condition of the occupants could also be reported. In that way the emergency service (EMS) would know what equipment and how many ambulances to send to the accident site.

Vehicle entertainment system engineers have stated that the quality of the sound in the vehicle could be improved if the number, size and location of occupants and other objects were known. This information can be provided by the vehicle interior identification and monitoring system of this invention.

Similarly to the entertainment system, the heating, ventilation and air conditioning system (HVAC) could be improved if the number, attributes and location of vehicle occupants were known. This can be used to provide a climate control system tailored to each occupant, for example, or the system can be turned off for certain seat locations if there were no occupant present.

In some cases the position of a particular part of the occupant is of interest such as: (a) his hand or arm and

whether it is in the path of a closing window so that the
motion of the window needs to be stopped; (b) the position
of the shoulder so that the seat belt anchorage point can
be adjusted for the best protection of the occupant; or,
(c) the position of the rear of the occupants head so that
the headrest can be adjusted to minimize whiplash injuries
in rear impacts.

The above applications illustrate the wide range of
opportunities which become available if the identity and
location of various objects and occupants, and some of
their parts, within the vehicle were known. Once the
system is operational it would be logical for the system to
also incorporate the airbag electronic sensor and
diagnostics system (SDM) since it needs to interface with
SDM anyway and since they could share computer capabilities
which will result in a significant cost saving to the auto
manufacturer. For the same reasons, it would be logical
for VIMS to include the side impact sensor and diagnostic
system. As the VIMS improves to where such things as the
exact location of the occupants ears and eyes can be
determined, even more significant improvements to the
entertainment system become possible through the use of
noise canceling sound, and the rear view mirror can be
automatically adjusted for the driver's eye location.
Another example involves the monitoring of the driver's
behavior over time which can be used to warn a driver if he

or she is falling asleep, or to stop the vehicle if the driver loses the capacity to control it.

Using an advanced VIMS, as explained below, the position of the driver's eyes can be accurately determined and portions of the windshield can be selectively darkened to eliminate the glare from the sun or oncoming vehicle headlights. This system uses electro-chromic glass, a liquid crystal coating on the glass, or other appropriate technology, and detectors to detect the direction of the offending light source. In addition to eliminating the glare, the sun visor can now also be eliminated.

The present invention adds more sophisticated pattern recognition capabilities such as fuzzy logic systems, neural network systems or other pattern recognition computer based algorithms to the occupant position measurement system disclosed in the above reference copending patent application and greatly extends the areas of application of this technology. An example of such a pattern recognition system using neural networks using sonar is discussed in two papers by Gorman, R,. P. and Sejnowski, T. J. `` Analysis of Hidden Units in a Layered Network Trained to Classify Sonar Targets'', *Neural Networks*, Vol.1. pp 75-89, 1988, and ``Learned Classification of Sonar Targets Using a Massively Parallel Network'', IEEE Transactions on Acoustics, Speech, and Signal Processing, Vol. 36, No. 7, July 1988.

``Pattern recognition'' as used herein will mean any
system which processes a signal that is generated by an
object, or is modified by interacting with an object, in
order to determine which one of a set of classes that the
object belongs to. Such a system might determine only that
the object is or is not a member of one specified class, or
it might attempt to assign the object to one of a larger
set of specified classes, or find that it is not a member
of any of the classes in the set. The signals processed
are generally electrical signals coming from transducers
which are sensitive to either acoustic or electromagnetic
radiation and if electromagnetic they can be either visible
light, infrared, ultraviolet or radar.

``To identify'' as used herein will mean to determine
that the object belongs to a particular set or class. The
class may be one containing all rear facing child seats,
one containing all human occupants, or all human occupants
not sitting in a rear facing child seat depending of the
purpose of the system. In the case where a particular
person is to be recognized, the set or class will contain
only a single element, the person to be recognized.

Some examples follow:

In a passive infrared system a detector receives
infrared radiation from an object in its field of view , in
this case the vehicle occupant, and determines the
temperature of the occupant based on the infrared
radiation. The VIMS can then respond to the temperature of

the occupant, which can either be a child in a rear facing
child seat or a normally seated occupant, to control some
other system. This technology could provide input data to
a pattern recognition system but it has limitations related
to temperature. The sensing of the child could pose a
problem if the child is covered with blankets. It also
might not be possible to differentiate between a rear
facing and forward facing child seat. In all cases, the
technology will fail to detect the occupant if the ambient
temperature reaches body temperature as it does in hot
climates. Nevertheless, for use in the control of the
vehicle climate, for example, a passive infrared system
which permits an accurate measurement of each occupant's
temperature is useful.

In a laser optical system an infrared laser beam is
used to momentarily illuminate an object, occupant or child
seat in the manner as described, and illustrated in FIG 8,
of the co-pending patent application cross referenced
above. In some cases a charge coupled device (a type of TV
camera) is used to receive the reflected light. The laser
can either be used in a scanning mode, or, through the use
of a lens, a cone of light can be created which covers a
large portion of the object. In each case a pattern
recognition system, as defined above, is used to identify
and classify, and can be used to locate, the illuminated
object and its constituent parts. This system provides the
most information about the object and at a rapid data rate.

Its main drawback is cost which is considerably above that of ultrasonic or passive infrared systems. As the cost of lasers comes down in the future, this system will become more competitive. Depending on the implementation of the system, there may be some concern for the safety of the occupant if the laser light can enter the occupant's eyes.

Radar systems have similar properties to the laser system discussed above. The wave length of a particular radar system can limit the ability of the pattern recognition system to detect object features smaller than a certain size. Once again, however, there is some concern about the health effects of radar on children and other occupants. This concern is expressed in various reports available from the United States Food and Drug Administration Division of Devices.

The ultrasonic system is the least expensive and potentially provides less information than the laser or radar systems due to the delays resulting from the speed of sound and due to the wave length which is considerably longer than the laser systems. The wave length limits the detail which can be seen by the system. In spite of these limitations, as shown below, ultrasonics can provide sufficient timely information to permit the position and velocity of an occupant to be accurately known and, when used with an appropriate pattern recognition system, it is capable of positively determining the presence of a rear facing child seat. One pattern recognition system which

has been used to identify a rear facing child seat uses
neural networks and is similar to that described in the
above referenced papers by Gorman et al.

A focusing system, such as used on some camera systems,
could be used to determine the initial position of an
occupant but is too slow to monitor his position during a
crash. This is a result of the mechanical motions required
to operate the lens focusing system. By itself it cannot
determine the presence of a rear facing child seat or of an
occupant but when used with a charge coupled device plus
some infrared illumination for night vision, and an
appropriate pattern recognition system, this becomes
possible.

From the above discussion, it can be seen that the
addition of sophisticated pattern recognition means to any
of the standard illumination and/or reception technologies
for use in a motor vehicle permits the development of a
host of new products, systems or capabilities heretofore
not available and as described in more detail below.

SUMMARY OF THE INVENTION

This invention is a system to identify and monitor
occupants and their parts and other objects in the
passenger compartment of a motor vehicle, such as an
automobile or truck, by processing the signal received from
said occupants and their parts and other objects using one
or more of a variety of pattern recognition techniques and

illumination technologies. The received signal may be a reflection of a transmitted signal, the reflection of some natural signal within the vehicle, or may be some signal emitted naturally by the object. Information obtained by the identification and monitoring system is then used to affect the operation of some other system in the vehicle. The principle objects and advantages are:

1. To recognize the presence of a human on a particular seat of a motor vehicle and to use this information to affect the operation of another vehicle system such as the airbag system, heating and air conditioning system, or entertainment system, among others.

2. To recognize the presence of a human on a particular seat of a motor vehicle and then to determine his/her position and to use this position information to affect the operation of another vehicle system.

3. To recognize the presence of a human on a particular seat of a motor vehicle and then to determine his/her velocity relative to the passenger compartment and to use this velocity information to affect the operation of another vehicle system.

4. To determine the position of a seat in the vehicle using sensors remote from the seat and to use that information in conjunction with a memory system and appropriate actuators to position the seat to a predetermined location.

5. To determine the position, velocity or size of an occupant in a motor vehicle and to utilize this information to control the rate of gas generation, or the amount of gas generated, by an airbag inflator system.

6. To determine the fact that an occupant is not restrained by a seatbelt and therefore to modify the characteristics of the airbag system. This determination can be done either by monitoring the position of the occupant or through the use of a resonating device placed on the shoulder belt portion of the seatbelt.

7. To determine the presence or position of rear seated occupants in the vehicle and to use this information to affect the operation of a rear seat protection airbag for frontal impacts.

8. To determine the presence or position of occupants relative to the side impact airbag systems and to use this information to affect the operation of a side impact protection airbag system.

9. To determine the openness of a vehicle window and to use that information to affect another vehicle system.

10. To determine the presence of an occupant's hand or other object in the path of a closing window and to affect the window closing system.

11. To remotely determine the fact that a vehicle door is not tightly closed using an illumination transmitting and receiving system such as one employing electromagnetic or acoustic waves.

12. To determine the position of the shoulder of a vehicle occupant and to use that information to control the seatbelt anchorage point.

13. To determine the position of the rear of an occupant's head and to use that information to control the position of the headrest.

14. To recognize the presence of a rear facing child seat on a particular seat of a motor vehicle and to use this information to affect the operation of another vehicle system such as the airbag system.

15. To determine the total number of occupants of a vehicle and in the event of an accident to transmit that information, as well as other information such as the condition of the occupants, to a receiver remote from the vehicle.

16. To affect the vehicle entertainment system based on a determination of the size or location of various occupants or other objects within the vehicle passenger compartment.

17. To affect the vehicle heating, ventilation and air conditioning system based on a determination of the number, size and location of various occupants or other objects within the vehicle passenger compartment.

18. To determine the temperature of an occupant based on infrared radiation coming from that occupant and to use that information to control the heating, ventilation and air conditioning system.

19. To provide a vehicle interior monitoring system for determining the location of occupants within the vehicle and to include within the same system various electronics for controlling an airbag system.

20. To determine the approximate location of the eyes of a driver and to use that information to control the position of the rear view mirrors of the vehicle.

21. To monitor the position of the head of the vehicle driver and determine whether the driver is falling asleep or otherwise impaired and likely to lose control of the vehicle and to use that information to affect another vehicle system.

22. To monitor the position of the eye lids of the vehicle driver and determine whether the driver is falling asleep or otherwise impaired and likely to lose control of the vehicle and to use that information to affect another vehicle system.

23. To determine the location of the eyes of a vehicle occupant and the direction of a light source such as the headlights of an oncoming vehicle or the sun and to cause a filter to be placed in such a manner as to reduce the intensity of the light striking the eyes of the occupant.

24. To determine the location of the eyes of a vehicle occupant and the direction of a light source such as the headlights of a rear approaching vehicle or the sun and to cause a filter to be placed in such a manner as to

14

reduce the intensity of the light reflected from the rear view mirrors and striking the eyes of the occupant.

25. To determine the location of the ears of a vehicle occupant and to use that information to control the entertainment system so as to improve the quality of the sound reaching the occupant's ears through such methods as noise canceling sound.

26. To recognize a particular driver based on such factors as physical appearance or other attributes and to use this information to control another vehicle system such as a security system, seat adjustment, or maximum permitted vehicle velocity, among others.

These and other objects and advantages will become apparent from the following description of the preferred embodiments of the vehicle interior identification and monitoring system of this invention

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side planer view with parts cutaway and removed of a vehicle showing the passenger compartment containing a rear facing child seat on the front passenger seat and a preferred mounting location for an occupant and rear facing child seat presence detector.

FIG. 2 is a side planer view with parts cutaway and removed showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle cellular communication system.

15

FIG. 3 is a side planer view with parts cutaway and removed showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle heating and air conditioning system.

FIG. 4 is a side planer view with parts cutaway and removed showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle airbag system.

FIG. 5 is a side planer view with parts cutaway and removed showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle entertainment system.

FIG. 6 is a side planer view with parts cutaway and removed of a vehicle showing the passenger compartment containing a driver and a preferred mounting location for an occupant identification system.

FIG. 7A is a functional block diagram of the ultrasonic imaging system illustrated in FIG. 1 using a microprocessor.

FIG. 7B is a functional block diagram of the ultrasonic imaging system illustrated in FIG. 1 using an application specific integrated circuit (ASIC).

FIG. 8 is a side planer view with parts cutaway and removed of a vehicle showing the passenger compartment containing a box on the front passenger seat and a preferred mounting location for an occupant and rear facing child seat presence detector.

FIG. 9 is a side planer view with parts cutaway and removed of a vehicle showing the passenger compartment containing a driver and a preferred mounting location for an occupant position sensor for use in side impacts and also of a rear of occupant's head locator for use with a headrest adjustment system to reduce whiplash injuries in rear impact crashes.

FIG. 10 is a side planer view with parts cutaway and removed of a vehicle showing the passenger compartment containing a front passenger and a preferred mounting location for an occupant head detector and a preferred mounting location of an adjustable microphone and speakers.

FIG. 11 is a side planer view with parts cutaway and removed of a subject vehicle and an oncoming vehicle, showing the headlights of the oncoming vehicle and the passenger compartment of the subject vehicle, containing detectors of the driver's eyes and detectors for the headlights of the oncoming vehicle and the selective filtering of the light of the approaching vehicle's headlights through the use of electro-chromic glass in the windshield.

FIG. 12 is a side planer view with parts cutaway and removed of a vehicle and a following vehicle showing the headlights of the following vehicle and the passenger compartment of the leading vehicle containing a driver and a preferred mounting location for driver eyes and following vehicle headlight detectors and the selective filtering of

17

the light of the following vehicle's headlights through the use of electro-chromic glass in the rear view mirror.

FIG. 13 is a side planer view with parts cutaway and removed of a vehicle showing the passenger compartment containing a driver, a shoulder height sensor and a seatbelt anchorage adjustment system.

FIG. 14 is a side planer view with parts cutaway and removed of a seat in the passenger compartment of a vehicle showing the use of ultrasonic resonators to determine the position of the seat.

FIG. 15 is a side planer view with parts cutaway and removed of the passenger compartment of a vehicle showing the use of ultrasonic resonators to determine the position of the driver seatbelt.

FIG. 16 is a side planer view with parts cutaway and removed of the passenger compartment of a vehicle showing the use of an ultrasonic resonator to determine the openness of the driver window and of a system for determining the presence of an object, such as the hand of an occupant, in the window opening.

FIG. 17 is a side planer view with parts cutaway and removed of the passenger compartment of a vehicle showing the use of an ultrasonic resonator to determine the openness of the driver side door.

FIG. 18 is a side planer view with parts cutaway and remov d showing schematically the interface between the

vehicle interior monitoring system of this invention and
the vehicle security system.

FIG. 19 is a side planer view with parts cutaway and
removed showing schematically the interface between the
vehicle interior monitoring system of this invention and an
instrument panel mounted inattentiveness warning light or
buzzer and reset button.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 a side planer view, with parts cutaway and
removed, of a vehicle showing the passenger compartment
containing a rear facing child seat 110 on the front
passenger seat 120 and a preferred mounting location for an
occupant and rear facing child seat presence detector is
illustrated. In this implementation three ultrasonic
transducers 131, 132 and 133 are used. Transducer 132
transmits ultrasonic energy toward the front passenger seat
which is reflected, in this case by a rear facing child
seat 110, and the reflected waves are received by the
transducers 131 and 133. The signal received by
transducers 131 and 133 varies with time depending on the
shape of the object occupying the passenger seat, in this
case a rear facing child seat 110. Each object will
reflect back a signal having a different pattern. Also,
the pattern received by transducer 131 will differ slightly
from the pattern received by transducer 133. Through the
use of two transducers a sort of stereographic image is

19

received by the two transducers and recorded for analysis by processor 101. This image will differ for each object which is placed on the vehicle seat and it will also change for each position of a particular object and for each position of the vehicle seat.

The ``image'' recorded from each ultrasonic receiver is actually a time series of digitized data of the amplitude of the received signal versus time. Since there are two receivers, two time series are obtained which are processed by the processor 101. When different objects are placed on the front passenger seat the two images are different but there are also similarities between all images of rear facing child seats, for example, regardless of where on the vehicle seat it is placed and regardless of what company manufactured the child seat. Alternately, there will be similarities between all images of people sitting on the seat regardless of what they are wearing, their age or size. The problem is to find the ``rules'' which differentiate the occupant images from the rear facing child seat images. The similarities of these images for various child seats are frequently not obvious to a person looking at plots of the time series and thus computer algorithms are developed to sort out the various patterns.

The determination of these rules is central to the pattern recognition techniques used in this invention. In general three approaches have been useful, artificial intelligence, fuzzy logic and artificial neural networks.

In some implementations of this invention, such as the determination that there is an object in the path of a closing window as described below, the rules are sufficiently obvious that a trained researcher can look at the returned acoustic signals and devise a simple algorithm to make the required determinations. In others, such as the determination of the presence of a rear facing child seat or of an occupant, artificial neural networks are used to determine the rules. One such set of neural network software for determining the pattern recognition rules is available from the NeuralWare Corporation of Pittsburgh, Pennsylvania.

The system used for the determination of the presence of a rear facing child seat, of an occupant or of an empty seat was the artificial neural network. In this case the network operates on the two returned signals as sensed by transducers 131 and 133. Through a training session the system is taught to differentiate between the three cases. This is done by conducting a large number of experiments where all possible child seats are placed in all possible orientations on the front passenger seat. Similarly a sufficiently large number of experiments are run with human occupants and with boxes, bags of groceries and other objects. As many as 1000 such experiments are run before the neural network is sufficiently trained so that it can differentiate among the three cases and output the correct decision with a very high probability.

Once the network is determined, it is possible to examine the result using tools supplied by NeuralWare, for example, to determine the rules which were finally arrived at by the trial and error techniques. In that case, the rules can then be programmed into a microprocessor resulting in a fuzzy logic or other rule based system. Alternately, a neural computer can be used to implement the net directly. In either case, the implementation can be carried out by those skilled in the art of pattern recognition. If a microprocessor is used, a memory device is also required to store the data from the analog to digital converters which digitize the data from the receiving transducers. On the other hand, if a neural network computer is used, the analog signal can be fed directly from the transducers to the neural network input nodes and an intermediate memory is not required. Memory of some type is needed to store the computer programs in the case of the microprocessor system and if the neural computer is used for more than one task, a memory is needed to store the network specific values associated with each task.

An alternate system is shown in FIG. 2 which is a side planer view showing schematically the interface between the vehicle interior monitoring system of this invention and the vehicle cellular communication system. In this view, an occupant 210 is shown sitting on the front passenger seat 220 and two ultrasonic transducers 231 and 232 are

used. One of the transducers 232 in this case acts as both
a transmitter and receiver while transducer 231 acts only
as a receiver. Alternately, transducer 231 could serve as
both a transmitter and receiver or the transmitting
function could be alternated between the two devices. As
was also the case in FIG. 1 the transducers 231 and 232 are
attached to the vehicle buried in the A-pillar trim, where
their presence is disguised, and are connected to processor
101 which is also hidden in the trim. The A-pillar is the
roof support pillar which is closest to the front of the
vehicle and which, in addition to supporting the roof, also
supports the front windshield and the front door.

The interface between the monitoring system and the
cellular phone system is shown schematically by box 240
which outputs to an antenna 250. The transducers 231 and
232 in conjunction with the pattern recognition hardware
and software, which is implemented in processor 101 and is
packaged on a printed circuit board or flex circuit along
with the transducers 231 and 232, determine the presence of
an occupant within a few seconds after the vehicle is
started. Similar systems located to monitor the remaining
seats in the vehicle, also determine the presence of
occupants at the other seating locations and this result is
stored in the computer memory which is part of each
monitoring system processor 101. In the event of an
accident, the electronic system associated with the
cellular phone system interrogates the various interior

monitoring system memories and arrives at a count of the number of occupants in the vehicle, and in more sophisticated systems, even makes a determination as to whether each occupant was wearing a seatbelt and if he or she is moving after the accident. The phone system then automatically dials the EMS operator and the information obtained from the interior monitoring systems is forwarded so that a determination can be made as to the number of ambulances and other equipment to send to the accident site. Vehicles having this capability are not yet in service but are planned for the late 1990's. Such vehicles will also have a system, such as the global positioning system, which permits the vehicle to determine its exact location and to forward this information to the EMS operator.

The control of the heating, ventilating, and air conditioning (HVAC) system alone would probably not justify the implementation of an interior monitoring system at least until the time comes when electronic heating and cooling systems replace the conventional systems now used. Nevertheless, if the monitoring system is present it can be used to control the HVAC for a small increment in cost. The advantage of such a system is that since most vehicles contain only a single occupant, there is no need to direct heat or air conditioning to unoccupied seats. This permits the most rapid heating or cooling for the driver when the vehicle is first started and he is alone without heating or

cooling unoccupied seats. Since the HVAC system does consume energy, an energy saving also results by only heating and cooling the driver when he is alone.

FIG. 3 shows a side planer view of a vehicle passenger compartment showing schematically the interface 260 between the vehicle interior monitoring system of this invention and the vehicle heating and air conditioning system. Like numbers in FIG. 3, and the other figures herein, have the same meaning. In addition to the acoustic transducers 231 and 232, an infrared sensor 234 is also shown which monitors the temperature of the occupant. The output from each of the transducers is fed into processor 101 which is in turn connected to interface 260. In this manner the HVAC control is based on the occupant's temperature rather than that of the ambient air in the vehicle. This also permits each vehicle occupant to be independently monitored and the HVAC system to be adjusted for each occupant either based on a set temperature for all occupants or, alternately, each occupant could be permitted to set his own preferred temperature through adjusting a control knob shown schematically as 250 in FIG. 3. Since the monitoring system is already installed in the vehicle with its own associated electronics including processor 101, the infrared sensor can be added with little additional cost and can share the processing unit.

The use of the vehicle interior monitoring system to control the deployment of an airbag is discussed in detail

in the co-pending patent application cross referenced above. In that case, the control is based on the use of a simple pattern recognition system to differentiate between the occupant and his extremities in order to provide an accurate determination of the position of the occupant relative to the airbag. If the occupant is sufficiently close to the airbag module that he is more likely to be injured by the deployment itself than by the accident, the deployment of the airbag is suppressed. This process is carried further by the interior monitoring system described herein in that the nature of the object occupying the vehicle seat is used to contribute to the airbag deployment decision. FIG. 4 shows a side planer view illustrating schematically the interface between the vehicle interior monitoring system of this invention and the vehicle airbag system 270.

In this case an ultrasonic transducer 232 transmits a burst of ultrasonic waves which travel to the occupant where they are reflected back to receptors 231 and 232. The time period required for the waves to travel from the generator and return is used to determine the distance of the occupant to the airbag as described in the aforementioned co-pending patent application. In the case of this invention, however, the portion of the return signal which represents the occupants head or chest has been determined based on pattern recognition techniques such as a neural network. The relative velocity of the

occupant toward the airbag can then be determined, from successive position measurements, which permits a sufficiently accurate prediction of the time when the occupant would become proximate to the airbag. By comparing the occupant relative velocity to the integral of the crash deceleration pulse, a determination as to whether the occupant is being restrained by a seatbelt can also be made which then can affect the airbag deployment initiation decision. Alternately, the mere knowledge that the occupant has moved a distance which would not be possible if he were wearing a seatbelt gives information that he is not wearing one.

A more detailed discussion of this process and of the advantages of the various technologies, such as acoustic or electromagnetic, can be found in SAE paper 940527, "Vehicle Occupant Position Sensing" by Breed et al, which is included herein by reference. In this paper it is demonstrated that the time delay required for acoustic waves to travel to the occupant and return does not prevent the use of acoustics for position measurement of occupants during the crash event. For position measurement and for many pattern recognition applications, ultrasonics is the preferred technology due to the lack of adverse health effects and the low cost of ultrasonic systems compared with either laser or radar. The main limiting feature of ultrasonics is the wave length which places a limitation on the size of feature which can be discerned. Optical

27

systems, for example, are required when the identification
of particular individuals is required.

It is well known among acoustics engineers that the
quality of sound coming from an entertainment system can be
substantially affected by the characteristics and contents
of the space in which it operates and the surfaces
surrounding that space. When an engineer is designing a
system for an automobile he has a great deal of knowledge
about that space and of the vehicle surfaces surrounding
it. He has little knowledge of how many occupants are
likely to be in the vehicle on a particular day, however,
and therefore the system is a compromise. If the system
knew the number and position of the vehicle occupants, and
maybe even their size, then adjustments could be made in
the system output and the sound quality improved. FIG. 5,
therefore, illustrates schematically the interface between
the vehicle interior monitoring system of this invention
and the vehicle entertainment system 280. The particular
design of the entertainment system which uses the
information provided by the monitoring system can be
determined by those skilled in the appropriate art.

The maximum acoustic frequency which is practical to
use for acoustic imaging in the systems is about 40 to 60
kilohertz (KHz). The wave length of a 50 KHz acoustic wave
is about .6 cm which is too coarse to determine the fine
features of a person's face, for example. It is well
understood by those skilled in the art that features which

28

are smaller that the wavelength of the illuminating

radiation cannot be distinguished. Similarly the wave

length of common radar systems varies from about .9 cm (for

33,000 MHz K band) to 133 cm (for 225 MHz P band) which is

also too coarse for person identification systems. In FIG.

6, therefore, the ultrasonic transducers of the previous

designs are replaced by laser transducers 231 and 232 which

are connected to a microprocessor 101. In all other

manners the system operates the same. The design of the

electronic circuits for this laser system is described in

some detail in the co-pending patent application cross-

referenced above and in particular FIG. 8 thereof and the

corresponding description. In this case a pattern

recognition system such as a neural network system is

employed and uses the demodulated signals from the

receptors 231 and 232.

The output of processor 101 of the monitoring system is

shown connected schematically to a general interface 290

which can be the vehicle ignition enabling system; the

entertainment system; the seat, mirror, suspension or other

adjustment systems; or any other appropriate vehicle

system.

There are two preferred methods of implementing the

vehicle interior monitoring system of this invention, a

microprocessor system and an application specific

integrated circuit system (ASIC). Both of these systems

are represented schematically as either 101 or 601 herein.

A block diagram illustrating the microprocessor system is shown in FIG. 7A which shows the implementation of the system of FIG. 1. An alternate implementation of the FIG. 1 system using an ASIC is shown in FIG. 7B. In both cases the target, which may be a rear facing child seat, is shown schematically as 110 and the three transducers as 131, 132, and 133.

In FIG. 8 a view of the system of FIG. 1 is illustrated with a box 295 shown on the front passenger seat in place of the rear facing child seat. The vehicle interior monitoring system of this invention is trained to recognize that this box 295 is neither a rear facing child seat nor an occupant and therefore it is treated as an empty seat and the deployment of the airbag is suppressed. This training is accomplished using a neural network with the commercially available software disclosed above and provided by NeuralWare of Pittsburgh. The system assesses the probability that the box is a person, however, and if there is even the remotest chance that it is a person, the airbag deployment is not suppressed. The system is thus typically biased toward airbag deployment.

Side impact airbags are now beginning to be used on some vehicles. These initial airbags are quite small compared to the driver or passenger airbags used for frontal impact protection. Nevertheless, a small child could be injured if he is sleeping with his head against the airbag when it deploys and a vehicle interior

monitoring system is needed to prevent such a deployment in that event. In FIG. 9 a single ultrasonic transducer 330 is shown mounted in the vehicle door adjacent to the airbag system. This device is not used to identify the object which is adjacent the airbag but merely to measure the position of the object.

A rear-of-head detector 334 is also illustrated in FIG 9. This detector is used to determine the distance from the headrest to the rear most position of the occupant's head and to therefore control the position of the headrest so that it is properly positioned behind the occupant's head to offer optimum support in the event of a rear impact. Although the headrest of most vehicles is adjustable, it is rare for an occupant to position it properly if at all. Each year there are in excess of 400,000 whiplash injuries in vehicle impacts approximately 90,000 of which are from rear impacts (source: National Highway Traffic Safety Administration, (NHTSA)). A properly positioned head rest could substantially reduce the frequency of such injuries which can be accomplished by the head detector of this invention. The head detector 334 is shown connected schematically to the headrest control mechanism and circuitry 340. This mechanism is capable of moving the headrest up and down and, in some cases, rotating it fore and aft.

When the driver of a vehicle is using a cellular phone, the phone microphone frequently picks up other noise in the

31

vehicle making it difficult for the other party to hear what is being said. This noise can be reduced if a directional microphone is used and directed toward the mouth of the driver. This is difficult to do since position of drivers' mouths varies significantly depending on such things as the size and seating position of the driver. By using the vehicle interior identification and monitoring system of this invention and through appropriat pattern recognition techniques, the location of the driver's head can be determined with sufficient accuracy even with ultrasonics to permit a directional microphone having a 15 degree cone angle to be aimed at the mouth of the driver resulting in a clear reception of his voice. Such a system can also be used to permit effortless conversations between occupants of the front and rear seats. Such a system is shown in FIG. 10 which is a system similar to that of FIG. 2 only using three ultrasonic transducers 231, 232 and 233 to determine the location of the driver's head and control the pointing direction of microphone 355. Speaker 357 is shown connected schematically to the phone system 359 completing the system.

The transducers 231 and 232 are placed high in the A-pillar and the third transducer 233 is placed in the headliner and displaced horizontally from transducers 231 and 232. the two transducers 231 and 232 provide information to permit the determination of the locus of th

32

head in the vertical direction and the combination of one of 231 and 232 in conjunction with 233 is used to determine the horizontal location of the head. The three transducers are placed high in the vehicle passenger compartment so that the first returned signal is from the head. Temporal filtering is used to eliminate signals which are reflections from beyond the head and the determination of the head center location is then found by the approximate centroid of the head returned signal. That is, once the location of the return signal centroid is found from each of the three received signals from transducers 231, 232 and 233, the distance to that point is known for each of the transducers based on the time it takes the signal to travel from the head to each transducer. In this manner by using the three transducers plus an algorithm for finding the coordinates of the head center, using processor 101, and through the use of known relationships between the location of the mouth and the head center, an estimate of the mouth location can be easily determined within a circle having a diameter of about five inches (13 cm). This is sufficiently accurate for a directional microphone to cover the mouth while excluding the majority of unwanted noise.

The headlights of oncoming vehicles frequently make it difficult for the driver of a vehicle to see the road and safely operate the vehicle. This is a significant cause of accidents and much discomfort. The problem is especially severe during bad weather where rain can cause multiple

33

reflections. Visors are now used to partially solve this problem but they do so by completely blocking the view through a large portion of the window and therefore cannot be used to cover the entire windshield. Similar problems happen when the sun is setting or rising and the driver is operating the vehicle in the direction of the sun. The vehicle interior monitoring system of this invention can contribute to the solution of this problem by determining the position of the driver's eyes. If separate sensors are used to sense the direction of the light from the on-coming vehicle or the sun and through the use of electro-chromic glass or a liquid crystal film, a portion of the windshield can be darkened to impose a filter between the eyes of the driver and the light source. Electro-chromic glass is a material where the color of the glass can be changed through the application of an electric current. By dividing the windshield into a controlled grid or matrix of contiguous areas and through feeding the current into the windshield from orthogonal directions, selective portions of the windshield can be darkened as desired.

FIG. 11 illustrates how such a system operates. A sensor 410 located on vehicle 402 determines the direction of the light from the headlights of oncoming vehicle 404. Sensor 410 is comprised of a lens and a charge coupled device (CCD) with appropriate electronic circuitry which determines which elements of the CCD are being most brightly illuminated. An algorithm stored in processor 101

34

then calculates the direction of the light from the oncoming headlights based on the information from the CCD. Transducers 231, 232 and 233 determine the probable location of the eyes of the operator 210 of vehicle 402 in a manner such as described above in conjunction with the determination of the location of the driver's mouth in the discussion of FIG. 10. In this case, however, the determination of the probable locus of the driver's eyes is made with an accuracy of a diameter for each eye of about 3 inches (7.5 cm). This calculation sometimes will be in error and provision is made for the driver to make an adjustment to correct for this error as described below.

The windshield 416 of vehicle 402 is made from electro-chromic glass or comprises a liquid crystal film and is selectively darkened at area 418 due to the application of a current along perpendicular directions 422 and 424 of windshield 416. The particular portion of the windshield to be darkened is determined by processor 101. Once the direction of the light from the oncoming vehicle is known and the locations of the driver's eyes are known, it is a matter of simple trigonometry to determine which areas of the windshield matrix should be darkened to impose a filter between the headlights and the driver's eyes. This is accomplished by processor 101. A separate control system, not shown, located on the instrument panel, or at some other convenient location, allows the driver to select the amount of dark ning accomplished by the system from no

35

darkening to maximum darkening. In this manner the driver can select the amount of light which is filtered to suit his particular physiology. The sensor 410 can either be designed to respond to a single light source or to multiple light sources to be sensed and thus multiple portions of the vehicle windshield to be darkened.

As mentioned above, the calculations of the location of the driver's eyes using acoustic systems may be in error and therefore provision must be made to correct for this error. One such system permits the driver to adjust the center of the darkened portion of the windshield to correct for such errors through a knob on the instrument panel, steering wheel or other convenient location. Another solution permits the driver to make the adjustment by slightly moving his head. Once a calculation as to the location of the driver's eyes has been made, that calculation is not changed even though the driver moves his head slightly. It is assumed that the driver will only move his head to center the darkened portion of the windshield to optimally filter the light from the oncoming vehicle. The monitoring system will detect this initial head motion and make the correction automatically for future calculations.

Electro-chromic glass is currently used in rear view mirrors to darken the entire mirror in response to the amount of light striking an associated sensor. This substantially reduces the ability of the driver to see

objects coming from behind his vehicle. If one rear approaching vehicle, for example, has failed to dim his lights, the mirror will be darkened to respond to the light from that vehicle making it difficult for the driver to see other vehicles which are also approaching from the rear. If the rear view mirror is selectively darkened on only those portions which cover the lights from the offending vehicle, the driver is able to see all of the light coming from the rear whether the source is bright or dim. This permits the driver to see all of the approaching vehicles not just the one with the bright lights.

Such a system is illustrated in FIG. 12 where rear view mirror 460 is equipped with electro-chromic glass, or comprises a liquid crystal film, having the capability of being selectively darkened. Associated with mirror 460 is a light sensor 462 which determines the direction of light 412 from the headlights of rear approaching vehicle 405. In the same manner as above, transducers 231, 232 and 233 determine the location of the eyes of the driver 210. The signals from both sensor systems, 231, 232 plus 233 and 462, are combined in processor 101, where a determination is made as to what portions of the mirror should be darkened. Appropriate currents are then sent to the mirror in a manner similar to the windshield system described above.

Seatbelts are most effective when the upper attachment point to the vehicle is positioned vertically close to the

shoulder of the occupant being restrained. If the
attachment point is too low the occupant experiences
discomfort from the rubbing of the belt on his shoulder.
If it is too high the occupant may experience discomfort
due to the rubbing of the belt against his neck and the
occupant will move forward by a greater amount during a
crash which may result in his head striking the steering
wheel. Women in particular experience discomfort from an
improperly adjusted seatbelt anchorage point. For these
reasons it is desirable to have the upper seatbelt
attachment point located slightly above the occupant's
shoulder. To accomplish this for various sized occupants,
the location of the occupant's shoulder must be known which
can be accomplished by the vehicle interior monitoring
system described herein. Such a system is illustrated in
FIG. 13 which is a side planer view of a seatbelt anchorage
adjustment system. In this system a transmitter and
receiver 520 is positioned in a convenient location such as
the headliner located above and to the outside of the
occupant's shoulder. A narrow elliptical beam 521 of
energy is transmitted from transducer 520 in a manner such
that it illuminates the occupant's shoulder and headrest.
An appropriate pattern recognition system as described
above is then used to determine the location and position
of the shoulder. This information is fed to the seatbelt
anchorage height adjustment system 528, shown

schematically, which moves the attachment point 529 to the optimum vertical location.

Acoustic resonators are devices which resonate at a preset frequency when excited at that frequency. If such a device which has been tuned to 40 khz is subjected to ultrasonic radiation at 40 khz, for example, it will return a signal which is much stronger than the reflected radiation. If such a device is placed at a particular point in the passenger compartment of a vehicle the returned signal can be easily identified as a high magnitude narrow signal at a particular point in time which is proportional to the distance from the resonator to the receiver. Since this device can be easily identified it provides a particularly effective method of determining the distance to a particular point in the vehicle passenger compartment. If several such resonators are used they can be tuned to slightly different frequencies and therefore separated and identified by the circuitry. Using such resonators the positions of various objects in the vehicle can be determined. In FIG. 14 for example, three such resonators are placed on the vehicle seat and used to determine the location of the front and back of the seat and the top of the seat back. In this case transducers 231 and 232, mounted in the A-pillar 662, are used in conjunction with resonators 641, 642 and 643 to determine the position of the seat. This information is then fed to the seat memory and adjustment system, not shown,

eliminating the currently used sensors which are placed typically beneath the seat adjacent the seat adjustment motors. In the conventional system the seat sensors must be wired into the seat adjustment system and are prone to being damaged. By using the vehicle interior monitoring system alone with inexpensive passive resonators, the conventional seat sensors can be eliminated resulting in a cost saving to the vehicle manufacturer.

Resonators of the type described above can be used for making a variety of position measurements in the vehicle. These resonators are made to resonate at a particular frequency. If the number of resonators increases beyond a reasonable number, dual frequency resonators can be used. A pair of frequencies is then used to identify a particular location. Alternately, resonators tuned to a particular frequency can be used in combination with special transmitters, which transmit at the tuned frequency, which are designed to work with a particular resonator or group of resonators. The cost of the transducers is sufficiently low to permit special transducers to be used for special purposes.

Another application for a resonator of the type described is to determine the location of the seatbelt and therefore determine whether it is in use. If it is known that the occupants are wearing seatbelts, the airbag deployment threshold can be increased since the airbag is not needed in low velocity accidents if th occupants ar

already restrained by seatbelts. This will reduce the number of deployments for cases where the airbag provides little or no improvement in safety over the seatbelt. FIG. 15, for example, shows the placement of a resonator 602 onto the front surface of the seatbelt where it can be sensed by the transducers 231 and 232. Such a system can also be used to positively identify the presence of a rear facing child seat in the vehicle. In this case the resonator 603 is placed onto the forward most portion of the child seat, or in some other convenient position, as shown in FIG. 1.

Other uses for such resonators include placing them on doors and windows in order to determine whether either is open or closed. In FIG. 16, for example, such a resonator 604 is placed onto the top of the window and is sensed by transducers 611 and 612. In this case transducers 611 and 612 also monitor the space between the edge of the window glass and the top of the window opening. Many vehicles now have systems which permit the rapid opening of the window, called ``express open'', by a momentary push of a button. For example, when a vehicle approaches a toll booth, the driver needs only touch the window control button and the window opens rapidly. Some automobile manufacturers do not wish to use such systems for closing the window, called ``express close'', because of the fear that the hand of the driver, or of a child leaning forward from the rear seat, or som other object, could get caught between the window

and window frame. If the space between the edge of the window and the window frame were monitored with an interior monitoring system, this problem can be solved. The presence of the resonator 604 on the top of the window glass also gives a positive indication of where the top surface is and reflections from below that point can be ignored.

Various design variations of the window monitoring system are possible and the particular choice will depend on the requirements of the vehicle manufacturer and the characteristics of the vehicle. Two systems will be briefly described here.

In the first example, a single transmitter/receiver 613 is used in place of and located centrally midway between the transducers 611 and 612 shown in FIG. 16. A recording of the output of transducer 611 is made of the open window without an object in the space between the window edge and the top of the window frame. When in operation, the transducer 613 receives the return signal from the space it is monitoring and compares that signal with the stored signal referenced above. This is done by processor 601. If the difference between the test signal and the stored signal indicates that there is a reflecting object in the monitored space, the window is prevented from closing in the express close mode. If the window is part way up, a reflection will be r ceived from the edge of the window glass which, in most cases, is easily identifiable from the

42

reflection of a hand for example. A simple algorithm based
on the intensity of the reflection in most cases is
sufficient to determine that an object rather than the
window edge is in the monitored space. In other cases, the
algorithm is used to identify the window edge and ignore
that reflection and all other reflections which are lower
(i.e. later in time) than the window edge. In all cases,
the system will default in not permitting the express close
if there is any doubt. The operator can still close the
window by holding the switch in the window closing position
and the window will then close slowly as it now does in
vehicles without the express close feature.

In the second system, two transducers 611 and 612 are
used as shown in FIG. 16 and the processor 601 comprises a
neural network. In this example the system is trained for
all cases where the window is down and at intermediate
locations. In operation, the transducers monitor the
window space and feed the received signals to processor
601. As long as the signals are similar to one of the
signals for which the network was trained, the express
close system is enabled. As before, the default is to
suppress the express close.

The use of a resonator to determine whether the vehicle
door is properly shut is illustrated in FIG. 17. In this
case the resonator 702 is placed in the B-pillar in such a
manner that it is shielded by the door, or by a cover or
other inhibiting mechanism (not shown) engaged by the door,

43

and prevented from resonating when the door is closed. If transducers such as 231 and 232 in FIG. 3 are used in this system, the closed door condition would be determined by the absence of a return signal from the B-pillar 702 resonator. This system permits the substitution of an inexpensive resonator for a more expensive and less reliable electrical switch.

The use of an acoustic resonator has been described above. For those cases where an infrared laser system is used, an optical mirror would replace the mechanical resonator used with the acoustic system. In the acoustic system, the resonator can be any of a variety of tuned resonating systems including an acoustic cavity or a vibrating mechanical element.

A neural network, or other pattern recognition system, can be trained to recognize certain people as permitted operators of a vehicle. In this case if a non-recognized person attempts to operate the vehicle, the system can disable the vehicle and/or sound an alarm as illustrated in FIG. 18. In this figure the sensing transducers are shown as before as 231, 232 and 233, the alarm system schematically as 708 and the alarm as 705. Since it is unlikely that an unauthorized operator will resemble the authorized operator, the neural network system can be quite tolerant of differences in appearance of the operator. The system defaults to where a key must be used in the case that the system doesn't recognize the driver or the owner

44

wishes to allow another person to operate the vehicle. The

transducers 231, 232 and 233 are sensitive to infrared

radiation and the operator is illuminated with infrared

waves from transducer 231. This is necessary due to the

small size of the features which need to be recognized for

high accuracy of recognition. An alternate system uses an

infrared laser, which can be 231 in FIG 18, to illuminate

the operator and a CCD device, which can be represented as

232 in FIG. 18, to receive the reflected image. In this

case the recognition of the operator is accomplished using

a pattern recognition system such as described in Popesco,

V. and Vincent, J.M. ``Location of Facial Features Using a

Boltzmann Machine to Implement Geometric Constraints'',

Chapter 14 of Lisboa, P.J.G. and Taylor, M.J. Editors,

Techniques and Applications of Neural Networks, Ellis

Horwood Publishers, New York, 1993. In the present case a

larger CCD element array containing 1000 or more elements

would in many cases be used instead of the 16 by 16 or 256

element CCD array used by Popesco and Vincent.

Once a vehicle interior monitoring system employing a

sophisticated pattern recognition system, such as a neural

network or fuzzy logic system, is in place, it is possible

to monitor the motions of the driver over time and

determine if he is falling asleep or has otherwise become

incapacitated. In such an event, the vehicle can be caused

to respond in a number of different ways. One such system

is illustrated in FIG. 19 and consists of a monitoring

system having transducers 231, 232 and 233 plus

microprocessor 101, such as shown in FIG. 7A, programmed to

compare the motions of the driver over time and trained to

recognize changes in behavior representative of becoming

incapacitated. If the system determines that there is a

reasonable probability that the driver has fallen asleep,

for example, then it can turn on a warning light shown here

as 805 or send a warning sound. If the driver fails to

respond to the warning by pushing a button 806, for

example, then the horn and lights can be operated in a

manner to warn other vehicles and the vehicle brought to a

stop. Naturally other responses can also be programmed.

An even more sophisticated system of monitoring the

behavior of the driver is to track his eye motions using

such techniques as are described in: Freidman et al, US

Patent 4,648,052 `'Eye Tracker Communication System'';

Heyner et al, US Patent 4,720,189 `'Eye Position Sensor'';

Hutchinson US Patent 4,836,670 `'Eye Movement Detector'';

and, Hutchinson US Patent 4,950,069 `'Eye Movement Detector

With Improved Calibration and Speed'', all of which are

included herein by reference. The detection of the

impaired driver in particular can be best determined by

these techniques. Also, in a similar manner as described

in these patents, the motion of the driver's eyes can be

used to control various systems in the vehicle permitting

hands off control of the entertainment system, heating and

air conditioning system or all of the other systems described above.

In most of the applications described above, a single frequency energy was used to illuminate various occupying items of the passenger compartment. This was for illustrative purposes only and this invention is not limited to single frequency illumination. In many applications, it is useful to use several discrete frequencies or a band of frequencies. In this manner considerably greater information is received from the reflected illumination permitting greater discrimination between different classes of objects. In general each object will have different reflectivities at each frequency. Also, the different resonators placed at different positions in the passenger compartment can now be tuned to different frequencies making it easier to isolate one resonator from another.

Although several preferred embodiments are illustrated and described above, there are possible combinations using other geometries, sensors, materials and different dimensions for the components that perform the same functions. This invention is not limited to the above embodiments and should be determined by the following claims.

47

CLAIMS

1.   In a motor vehicle having an interior passenger compartment, said compartment having contents comprising one or more objects and/or occupants, an interior monitoring system comprising:

5   a)   Pattern recognition means to identify at least one of said contents or a part of one of said contents;

         b)   Means to determine the location of said identified content or part of one of said contents; and

         c)   Output means to effect another system within said vehicle,
10   in response to said location determination.

2.   A system according to claim 1 in which the contents of the passenger compartment includes at least one occupant.

3.   A system according to claim 2 in which the pattern recognition means identifies a part of the or each occupant and the means to
15   determine the location, determines the location of said part.

4.   A system according to claim 5 in which the part of the or each occupant are the eyes of the or each occupant.

5.   A system according to any one of the preceding claims in which the Pattern recognition means includes means to irradiate the contents of the
20   passenger compartment.

6.   The invention in accordance with any one of claims 2 to 5 in which said other system is an airbag system for protection of the occupants of the vehicle.

7.   The invention in accordance with any one of claims 2 to 5 in which

said other system is a gas generator of an airbag system, said gas generator being of the variable inflation rate type and said invention further comprising means to control the inflation rate of said variable inflation rate inflator based on the position of said occupant.

5   8.   The invention in accordance with any one of claims 1 to 5 in which said other system is a rear view mirror.

9.   The invention in accordance with any one of claims 1 to 5 in which said other system is an adjustable seatbelt anchorage system.

10.   The invention in accordance with any one of claims 1 to 5 in which
10   said other system is an adjustable headrest system.

11.   The invention in accordance with claim 4, further comprising means for determining the direction of an external light source;
        said output means in response to the determined location of the
        eyes of the occupant and the direction of the external light source,
15   being arranged to activate a light filter between the external light
        source and the determined location of the eyes of the occupant.

12.   The invention in accordance with claim 2, in which said pattern recognition means comprise means for illuminating an occupant, means for receiving reflected illumination from the occupant and means for
20   processing the received reflected illumination to create an electronic signal;
        the attentiveness of the occupant being determined from
        successive determinations of the location of the occupant by said
        location determining means and said output means being arranged
25   to effect the another system based on the determined attentiveness
        of the occupant.

- 49 -

13.   The invention in accordance with any one of claims 1 to 12, in which said pattern recognition means comprise a trained neural network.

14.   The invention in accordance with claim 1, in which said pattern recognition means identify at least one of said contents which is an
5   occupying item and said at least one occupying item has surfaces, said at least one occupying item being of a certain class, said pattern recognition means comprising receiver means for receiving radiation from said surfaces of said at least one occupying item and processor means coupled to said receiver means for processing said received radiation in order to
10   create an electronic signal characteristic of said at least one occupying item based on said received radiation, said signal containing a pattern representative and characteristic of said at least one occupying item; said pattern recognition means identifying the class of said at least one occupying item by processing said signal based on said received radiation
15   from said surfaces of said at least one occupying item into a categorisation of said signal characteristic of said at least one occupying item;
       said location determining means being coupled to said processor means;
20   said output means being coupled to said pattern recognition means and said location determining means for affecting the another system based on the categorisation of said electronic signal characteristic of the least one occupying item and the determined location of the at least one occupying item.

25   15.   The invention in accordance with claim 14, further comprising means for irradiating a portion of said vehicle interior passenger compartment in which the at least one occupying item is situated.

       16.   The invention in accordance with claim 14 or claim 15, in which

- 50 -

said at least one occupying item is a rear facing child seat.

17. The invention in accordance with any one of claims 14 to 16, in which said output means produce an output representative of the number of occupants in said vehicle and said at least one other system is a vehicle communication system.

18. The invention in accordance with any one of claims 14 to 16, in which said output means produce an output representative of specific seat occupancy and said at least one other system is a vehicle entertainment system.

19. The invention in accordance with any one of claims 14 to 16, in which said output means produce an output representative of seat occupancy and said at least one other system is a vehicle heating and air conditioning system.

20. The invention in accordance with any one of claims 14 to 16, in which said at least one occupying item is at least an occupant, said invention further comprising measurement means for measuring the temperature of said vehicle occupant, said occupant temperature being output by said output means to said at least one other system.

21. The invention in accordance with claim 15, in which said irradiating means are selected from the group consisting of means for producing acoustic radiation and means for producing electromagnetic radiation.

22. The invention in accordance with any one of claims 14 to 21, in which the at least one occupying item is an occupant, further comprising determining means coupled to said processor means for receiving said electronic signal and determining the attentiveness of said occupant from

said electronic signal; and

second output means coupled to said determining means and to one of the systems in the vehicle for affecting said one of the systems in the vehicle in response to the determined attentiveness of said occupant.

23. The invention in accordance with any one of claims 14 to 22, in which said receiver means generate a signal which varies over time depending on the shape of the at least one occupying item.

24. The invention in accordance with any one of claims 14 to 16, in which said at least one other system within said vehicle is selected from the group consisting of:-

     (i)   an entertainment system;

     (ii)   a distress notification system;

     (iii)   a heating and air-conditioning system;

     (iv)   a vehicle safety system;

     (v)   a light filtering system; and

     (vi)   an unauthorised user/ignition enabling system.

25. The invention in accordance with any one of claims 14 to 24, in which said pattern recognition means comprise a trained neural network.

26. The invention in accordance with claim 1, in which said contents are of certain classes, said pattern recognition means comprising receiver means for receiving radiation from at least one of said contents in the compartment and generating a signal corresponding to the received radiation, said pattern recognition means recognising and thus identifying the class of said at least one of said contents by processing said signal corresponding to the received radiation into an identification of the class of said at least one of said contents,

said location determining means being coupled to said pattern recognition

- 52 -

means, and said output means being coupled to said location determining means for affecting at least one other system within the vehicle based on:-

(i)   the determined location of said at least one of said contents within said vehicle; and

(ii) ·· the identification of the class of said at least one of said contents within said vehicle.

27.   The invention in accordance with claim 26, in which said recognition and identification means further comprise means for irradiating said at least one of said contents of said compartment.

28.   The invention in accordance with claim 26 or claim 27, in which said at least one of said contents comprises an occupant.

29.   The invention in accordance with any one of claims 26 to 28, in which said vehicle further comprises a rear seat and said at least one other system is selected from the group consisting of an airbag system for frontal impact protection of an occupant of the front seat of the vehicl when the occupant is seated in the front seat, an airbag system for frontal impact protection of an occupant of the rear seat of the vehicle when the occupant is seated in the rear seat and an airbag system for side impact protection of an occupant.

30.   The invention in accordance with any one of claims 26 to 28, further comprising comparison means to compare the position of the occupant at different times after an accident and to thereby determine motion of the occupant and wherein said at least one other system is a vehicle communication system.

31.   The invention in accordance with any one of claims 26 to 28, in

which said at least one other system is an airbag system and means are further provided to determine the velocity of the occupant from successive location measurements.

32.   The invention in accordance with any one of claims 26 to 28, in which said at least one other system is an airbag system including a gas generator having a variable inflation rate, further comprising means to control the inflation rate of said gas generator based on the determined location of the occupant.

33.   The invention in accordance with any one of claims 26 to 28, in which said at least one other system is an airbag system including an electronic crash sensor having a sensor threshold triggering level and means for setting the sensor threshold triggering level, further comprising means to determine seatbelt usage of the occupant, said means for setting the sensor threshold triggering level of the electronic crash sensor being coupled to said seatbelt usage determining means and being structured and arranged to consider the seatbelt usage to set the sensor threshold triggering level.

34.   The invention in accordance with any one of claims 26 to 28, in which the contents constitute at least one occupant, said pattern recognition means being structured and arranged to recognise and identify at least one part of the at least one occupant and said location determining means being structured and arranged to determine the location of said at least one identified part of the at least one occupant within said passenger compartment.

35.   The invention in accordance with claim 34, in which said at least one part of the at least one occupant is the head, said output means affecting said at least one other system based at least in part on the

- 54 -

determined location of said head of the at least one occupant.

36.   The invention in accordance with claim 34, in which said at least one part of the at least one occupant are the eyes.

37.   The invention in accordance with claim 34, in which said at least
5   one other system is selected from the group consisting of an adjustable seatbelt anchorage system, an adjustable headrest system and a window closing system.

38.   The invention in accordance with any one of claims 26 to 28, in which said signal comprises a plurality of data, all of said data being
10   compared to data corresponding to patterns of received radiation stored within said pattern recognition means and associated with possible classes of contents of the vehicle.

39.   In a motor vehicle having an interior passenger compartment for enclosing at least one occupying item having surfaces and assigned to a
15   certain class, a method for controlling a system in the vehicle based on the at least one occupying item comprising the steps of:
           receiving radiation from said surfaces of the at least one occupying item within the passenger compartment;
           processing said received radiation in order to create at least one
20   electronic signal characteristic of the at least one occupying item within the passenger compartment based on said received radiation, each of said at least one signal containing a pattern representative and characteristic of the at least one occupying item;
           determining the location of the at least one occupying item within
25   the passenger compartment based on said received radiation;
           categorising each of said at least one signal by utilising pattern recognition means for recognising and thus identifying the class of the at

least one occupying item, said pattern recognition means processing each
of said at least one signals based on said received radiation from said
surfaces of the at least one occupying item into a categorisation of said
signal characteristic of the at least one occupying item; and

5   affecting the system in the vehicle based on the categorisation of
said at least one signal characteristic of the at least one occupying item
and the determined location of the at least one occupying item.

40.   The method of claim 39, further comprising the step of:
        irradiating at least a portion of the passenger compartment in which
10   the at least one occupying item is situated.

41.   The method of claim 39 or claim 40, in which the system in the
vehicle is a vehicle communication system, further comprising the steps
of:
        producing an output representative of the number of occupants in
15   the vehicle based on the categorisation of said at least one signal
characteristic of the at least one occupying item; and
        controlling the vehicle communication system based on the output
representative of the number of occupants in the vehicle.

42.   The method of claim 39 or claim 40, in which the system in the
20   vehicle is a vehicle entertainment system, further comprising the steps of:
        producing an output representative of specific seat occupancy
based on the categorisation of said at least one signal characteristic of the
at least one occupying item; and
        controlling the vehicle entertainment system based on the output
25   representative of specific seat occupancy.

43.   The method of claim 39 or claim 40, in which the system in the
vehicle is a vehicle heating and air conditioning system, further comprising

the steps of:

producing an output representative of specific seat occupancy based on the categorisation of said at least one signal characteristic of the at least one occupying item; and

5   controlling the vehicle heating and air conditioning system based on the output representative of specific seat occupancy.

44.   The method of any one of claims 39 to 43, further comprising the steps of:

arranging temperature measurement means for measuring the

10   temperature of an occupant of the passenger compartment; and

in addition to affecting the system in the vehicle based on the categorisation of said at least one signal characteristic of the at least one occupying item and the determined location of the at least one occupying item, affecting the system in the vehicle based on the measured

15   temperature of the occupant.

45.   The method of any one of claims 39 to 43, further comprising the steps of:

determining attentiveness of the at least one occupying item from said at least one signal if the at least one occupying item is an occupant;

20   and

in addition to affecting the system in the vehicle based on the categorisation of said at least one signal characteristic of the at least one occupying item and the determined location of the at least one occupying item, affecting the system in the vehicle based on the determined

25   attentiveness of the occupant.

46.   The method of any one of claims 39 to 43, in which said received radiation is processed to generate at least one signal which varies ov r tim depending on the shape of th at least one occupying item.

- 57 -

47. The method of any one of claims 39 to 46, in which said pattern recognition means comprise a trained neural network.

48. The method of claim 39 or claim 40, in which the vehicle further comprises a rear seat and the system is selected from a group consisting of an airbag system for frontal impact protection of an occupant of the front seat of the vehicle when the occupant is seated in the front seat, an airbag system for frontal impact protection of an occupant of the rear seat of the vehicle when the occupant is seated in the rear seat and an airbag system for side impact protection of an occupant.

49. The method of claim 39 or claim 40, further comprising the step of:
comparing the location of the at least one occupying item at different times to thereby determine motion of the at least one occupying item.

50. The method of claim 39 or claim 40, further comprising the step of:
determining the velocity of the at least one occupying item from successive location measurements.

51. The method of claim 39 or claim 40, in which the system is an airbag system including a gas generator having a variable inflation rate, further comprising the step of controlling the inflation rate of said gas generator based on the determined location of the at least one occupying item.

52. The method of claim 39 or claim 40, in which the system is an airbag system including means for controlling the flow of gas into or out of an airbag further comprising the step of controlling said flow of said gas into or out of said airbag based on the determined location of th at

- 58 -

least one occupying item.

53.   The method of claim 39 or claim 40, in which the system is an airbag system including an electronic crash sensor having a sensor threshold triggering level and means for setting the sensor threshold triggering level, further comprising the step of determining seatbelt usage of the occupant, said means for setting the sensor threshold triggering level of the electronic crash sensor being coupled to said seatbelt usage determining means and being structured and arranged to consider the seatbelt usage to set the sensor threshold triggering level.

54.   The method of claim 39 or claim 40, in which the step of receiving radiation from said surfaces of the at least one occupying item comprises the step of arranging a plurality of receivers in the vehicle each at a discrete location, said received radiation from each of said receivers being processed in order to create a respective electronic signal characteristic of the at least one occupying item within the passenger compartment based on said received radiation from said receiver, each of said electronic signals being categorised by utilising said pattern recognition means.

55.   The method of claim 39 or claim 40, in which said pattern recognition means are structured and arranged to additionally use information from another sensor when recognising and thus identifying the class of the at least one occupying item.

56.   The method of claim 55, in which said another sensor is selected from a group consisting of a weight sensor, a seatbelt buckle sensor a seatbelt payout sensor, a seat position sensor, and a seatback angle sensor.

57.   In a motor vehicle having an interior passenger compartment having

(i) at least one occupant, said occupant having eyes, (ii) a windshield and (iii) a rear view mirror, a monitoring system comprising:

    a.   Pattern recognition means to determine the direction of an external light source;

5   b.   Means to determine the location of the eyes of said occupant; and

    c.   Means responsive to the direction of said external light source and said location of said eyes to automatically activate a light filter between said external light source and

10   the eyes of said occupant.

58.   In a motor vehicle having an interior passenger compartment containing at least one occupant, an occupant attentiveness detection system comprising:

    a.   Means to illuminate said occupant;

15   b.   Means to receive reflected illumination from said occupant;

    c.   Means to process said received illumination to create an electronic signal;

    d.   Means to determine the attentiveness of said occupant from said electronic signal; and

20   e.   Output means in response to said attentiveness determination to affect at least one other system within said vehicle.

59.   A vehicle interior monitoring system substantially as described with reference to and as illustrated in any of the figures of the accompanying

25   drawings.

The Patent Office

Application No: GB 9816593.9	**Examiner:** Andrew Bartlett
Claims searched: 1 & 39	**Date of search:** 27 August 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P):

Int Cl (Ed.6): B60J 3/04 & 3/06; B60R 1/08, 21/00, 22/20 & 22/48

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	US 5298732 (CHEN) See columns 10 & 12 in particular	1-5, 11, 39, 40 at least
X	US 5118134 (MATTES ET AL) Whole document	1-3,5-7, 39,40 at least
X	US 5071160 (WHITE ET AL) Whole document	-
X	US 5008946 (ANDO) Whole document	1-5,14,19, 24 39,40, 43 at least
X	US 4645233 (BRUSE ET AL) Whole document	1-3,5,9, 10, 39 at least
X,E	WO 95/27635 A1 (AEROJET) Whole document	1-3,5-7, 14-16, 21, 24,39, 40, 51,52 at least
X,P	WO 94/23974 A1 (AUTOMOTIVE SYSTEMS)	1-3,5,6,39 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

The Patent Office

<u>62</u>

Application No:	GB 9816593.9	**Examiner:**	Andrew Bartlett
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